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SPACE

No. 21

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MANNED MISSION HIGHLIGHTS

LEONOV DESCRIBES COSMONAUTS' LANDING, PHYSICAL CONDITION

Moscow NEDELYA in Russian No 50, 13-19 Dec 82 p 5

[Interview with Major General of Aviation A.A. Leonov, twice Hero of the Soviet Union, pilot-cosmonaut of the USSR, by IZVESTIYA special correspondent B. Konovalov, at the Baykonur cosmodrome: "The Return"; date not specified]

[Text] [Question] Aleksandr Arkhipovich, as deputy chief of the cosmonaut training center you have had many occasions to greet crews at the landing site. What, in your opinion, was noteworthy about the landing of Anatoliy Berezovoy and Valentin Lebedev?

[Answer] Of all landings by cosmonauts after long-duration flights under weightless conditions, this was perhaps the most complex. The night landing itself is already fraught with the unexpected and with difficulties for the search service, and this time even the weather brought us a nasty surprise. The edge of a warm front covering the Dzhezkazgan steppe moved of its own accord, seemingly "not subject to" the weather forecast, and so complex conditions were created for the helicopters at Anatoliy Berezovoy's and Valentin Lebedev's landing site: low cloud and fog, followed by a snowfall with loose, blowing snow.

I spent the entire night at the command point. They were very tense hours for everyone. The commander of the lead helicopter, N.V. Karasev, descended vertically several times and found himself in a snow bank, held up by his rotor blades. Even with his lights he could not see the ground. The search leaders told him: "Land at your own discretion." There were 10 people aboard the helicopter, but he nevertheless accepted the responsibility and made a landing that in flying circles they call a roll-on landing. Unfortunately, he rolled into a dry river bed and the left wheel was smashed. But the main thing had been accomplished. This helicopter acted as "pathfinder" for the second helicopter and helped it to land. Then the weather deteriorated even more. The alternative recovery plan was put into effect: self-propelled search-and-recovery installations with physicians on board, already deployed at the most likely landing site, moved rapidly toward the actual landing site. They had to travel at night across steppe with no roads. They made it, and took the cosmonauts aboard. But we were not sure that the weather would improve on the following day. Which meant that if the helicopters were unable to fly, the next morning the crew would have be taken to Dzhezkazgan aboard the cross-country vehicles. As you can see, in the complex conditions the search-and-recovery service brought all its facilities into play in order to effect the safe recovery of the cosmonauts.

[Question] How do you assess the "El'brus" crew's readaptation to terrestrial conditions after such a long time under weightless conditions?

[Answer] Of course, 211 days of weightlessness are not without their effect on the body. When a cosmonaut returns to Earth the gravitational pull of our planet begins to affect him and every one of his cells. And this is why he must readapt. Cosmonauts after the landing now remind me of young saiga [aaspecies of antelope--ed] from Dzhezkazgan steppe. When they come into the world they must first lie down for awhile; then they jump up, stand on their feet and gradually learn to walk. It is exactly the same for a crew returning from a long-duration flight; and this gradual transfer to living on the Earth is very important. It was obvious that both Berezovoy and Lebedev had pinched faces and had grown thin and pale. The muscle volume had altered and their density had changed. There are also certain changes that can be detected only by instruments. Therefore, the process of readaptation is very complex. On the whole the physicians are not finding anything unexpected in the condition of Berezovoy and Lebedev and we expect that they will be home before the New Year.

[Question] What will Berezovoy and Lebedev do during these days at Baykonur? What are the pleasures of Earth that give them the greatest satisfaction?

[Answer] There is a program of detailed medical studies. For the first 5 days they will be completely under the control of the physicians and only a short time has been alloted for interviews with journalists. Then they will start work with the specialists to prepare the reports.

On the third day after the landing, the "El'brus" crew could no longer stand their solitary meals in the hospital rooms and they came down to the dining hall with everyone else. Of course, they badly missed just plain human contacts with their comrades. They have good appetites and are asking for chicken, cucumbers and tomatoes... They bathe each day in the pool, with an elevated oxygen content. This is not so much for water procedures, as they say, but to spend time in water-weightlessness [gidronevesomost'] and make their lives easier. It is a bit difficult for them to sit; their muscles have become unaccustomed to fulfilling their basic functions of making sitting easier.

[Question] Did the long flight leave any marks on the cosmonauts themselves or their interpersonal relations with the people around them?

[Answer] In my opinion, any person who has been in space assesses his place on Earth in a somewhat different light. He more often starts to think of Earth as the home of people, and of each person as someone close. He becomes kinder, more attentive; he does not react to trifles. And I note this in Berezovoy and Lebedev. They now think more broadly, and have become kinder and wiser. I sometimes think that if suddenly, in one beautiful moment we could take all mankind into space and go round our planet, afterwards much would changed here in life on Earth, and many problems would be solved...

[Question] How do you assess the work of the "El'brus" crew in orbit? What significance will this flight have for the further development of space research?

[Answer] While in orbit Berezovoy and Lebedev carried out about 300 scientific and technical, medical and biological and national economic experiments. An enormous amount of work was done and, of course, the specialists are pleased with them. The main thing is that they took an important step in increasing the duration of weightlessness, which will be essential for work on large orbiting stations, space plants and factories, and for interplanetary flights. We are still venturing into the unknown, and it is now clear that the next step forward can be taken and the exploration of the unknown continued.

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SALYUT-7 COSMONAUTS' PRESS CONFERENCE

Moscow Domestic Service in Russian 0755 GMT 6 Jan 83

[Press conference conducted by Sergey Aleksandrovich Kuznetsov, first deputy head of the Ministry of Foreign Affairs Press Department, at the Foreign Ministry Press Center]

[Excerpts] [Kuznetsov] Esteemed ladies and gentlemen, dear comrades: May I on your behalf welcome the heroes of the Cosmos, Anatoliy Nikolayevich Berezovoy and Valentin Vitaliyevich Lebedev, who recently completed a 211-day space flight and have come to the USSR Foreign Ministry Press Center for today's press conference on this event. Taking part in today's press conference are: academician Anatoliy Petrovich Aleksandrov, president of the Academy of Sciences; academician Vladimir Aleksandrovich Kotel'nikov, vice president of the Academy of Sciences; Yevgeniy Ivanovich Vorobyev, deputy USSR minister of health; academician Roald Zinnurovich Sagdeyev, director of the Space Research Institute; Prof Sergey Dmitriyevich Grishin, deputy head of the Flight Control Center; Prof Konstantin Petrovich Feoktistov, USSR pilot-cosmonaut; Vladimir Aleksandrovich Shatalov, USSR pilot-cosmonaut, head of cosmonaut training; Georgiy Timofeyevich Beregovoy, head of the Yuriy Aleksandrovich Gagarin Cosmonaut Training Center and USSR pilot-cosmonaut; Valeriy Viktorivich Ryumin, flight controller and USSR pilot-cosmonaut; Aleksey Arkhipovich Leonov, deputy head of the Yuriy Aleksandrovich Gagarin Cosmonaut Training Center and USSR pilot-cosmonaut.

May I give the floor to academician Anatoliy Petrovich Aleksandrov, president of the USSR Academy of Sciences:

[Aleksandrov] Cosmonauts Berezovoy and Lebedev carried out a very large number of scientific-technological experiments. The cosmonauts themselves will talk about these in detail, and for this reason I shall dwell only on a few studies--more than 40 observation sessions were held using X-ray telescopes. In particular, a so-called Seyfert galaxy was studied. Powerful X-ray radiation was observed there, with approximately 30 times the intensity of ordinary X-ray sources of average scale. Observation of this part of the sky from a ground observatory with an optical telescope showed an increase in luminosity of this galaxy after a certain delay, and the brightness corresponded to an increase of a whole stellar magnitude. The study of these two flares, in the X-ray spectrum and in the optical spectrum and the time difference between them is very important research, which will evidently bear substantial results and will make it possible to find our bearings in the hypotheses which exist to date. It is supposed that X-ray radiation is created in the deep regions of the galaxy, and the optical luminosity is connected with excitation of its external layers. Thus, this series of observations will make it possible to substantially expand our knowledge of Seyfert galaxies.

In the framework of a broad program of study of the earth's natural resources and environmental research, the cosmonauts constantly carried out both visual and instrument-aided observations and photography of the surface of the earth, and also observed various meteorological phenomena and photographed them. The work of Cosmonauts Berezovoy and Lebedev in this direction made it possible to gather important statistical material on the country's raw materials resources, on the seasonal changeability of agricultural lands and tracts of forest, and also on the biological productivity of the world's seas and fisheries conditions. For example, in October 1982, taking results of orbital research into account, six geological detachments searched for mineral deposits in the region of the Caspian, Aral and Balkhash.

The medical-biological results of this prolonged flight in space are of immense value. Any step, even the smallest, in the direction of increasing the length of space flight is of very great importance, because in the final analysis this is what will determine the possibility for work by cosmonauts on building any kind of space stations, observation points and so forth. Cosmonauts Anatoliy Berezovoy and Valentin Lebedev, and space medical experts together with them, entered a region which no person had until recently gone into; they moved forward the barrier of habitability, so to speak, of space by 26 days, that is, by almost a whole month. It is a fundamental medical result of the flight that the increase in the stay of a person in space to 7 months did not, compared with flights of lesser duration, lead to the emergence of any qualitatively new functional shifts in the organism of the cosmonauts. This is evidence of the maturity of space medicine. The principles and methods of medical checks, prevention of the unfavorable effects of weightlessness and of postflight rehabilitation measures drafted by Soviet specialists made it possible to maintain a good state of health and a high level of capability on the part of the cosmonauts for work throughout the 7-month flight and to ensure a speedy enough return by them to a normal state in the conditions of normal life on earth. We can see this in our neighbors.

The strategy of gradually and successively increasing the length of time man stays in space chosen by Soviet medical experts is fully justifying itself, and is making it possible for man to get used to living more and more confidently in space and to view with optimism the problems connected with even more prolonged stays and work in space. The main conclusion from the prolonged space expeditions is an important one: so far no insurmountable biological obstacles to prolonged stays in space by man of the order of a year, for example, have been discovered.

Much work was carried out in orbit by the crew comprising Leonid Popov, Aleksandr Serebrov and Svetlana Savitskaya, the second woman in the world to make a space flight. Without dwelling in detail on the results of their work, I shall note one important fact: the medical experts did not discover any kind of substantial differences between the reactions of the organism of a man and a woman in conditions of space flight. This allows us to view with optimism the participation of women in future space travel.

[Kuznetsov] The flight engineer of the spacecraft, twice Hero of the Soviet Union, Pilot-Cosmonaut Valentin Mikhaylovich Lebedev, will deliver a report on the scientific-technical research and experiments conducted on board the space complex. Please begin, Valentin Mikhaylovich.

[Lebedev] Esteemed comrades, ladies and gentlemen. As flight engineer whose responsibilities included the operation of the systems of the spacecraft and station and preparation of the scientific apparatus for experiments, I should like to note first of all that the Salyut-Soyuz-Progress orbital complex was made to a high technical standard and during the flight showed great reliability and great capacities. The new station differs from the Salyut-6 station both in comfort and in provision of scientific apparatus. However, the main advantage is probably that it is not only a scientific research base, but also a production base. We conducted about 300 experiments, research projects and many observations on behalf of dozens of departments representing various branches of the nation economy. Some of these have specific practical applications as well as scientific value. The main lines of research were astrophysics, geophysics, biology, biotechnology, studies of materials and medicine. The program of visual observations included tasks for geologists, oceanologists and specialists in agriculture and forestry. A series of technical experiments, was also carried out, directed toward the further development and improvement of space equipment.

I shall begin with the technological experiments, with which we concluded our program. The station now has on board two technological installations: "Magma" and "Korund." "Magma" is an installation that can be considered experimental. It is in effect the same "Kristall" installation that was improved before the Soviet-French expedition by agreement with the French side. Over 70 hours were spent using it, and a number of capsules with semiconductor materials were obtained: cadmium sulphide, selenide and gallium bismuthite.

"Korund" is a new generation installation. It combines the wider possibilities of technological furnaces for melting crystals as used on Salyut-6. As you will recall, in the "Splav" installation the heat field was varied to obtain semiconductor crystals, whereas in the "Kristall," with a constant heat field, the capsules were brought together at two speeds. The "Korund" uses a combined technique. The heat field can be varied from room temperature to 1,270 degrees, with a heating-up rate from a tenth of a degree to 10 degrees per minute. The rate of movement of the capsules can be from a few millimeters a day to hundreds of millimeters a minute. The capsules themselves have become bigger. Their length is 300 mm and their diameter 30 mm. Twelve capsules can be loaded into the drum of this installation simultaneously, and these can be treated in sequence in the heat field--in one loading, up to 12 kgs of most valuable semiconductor materials, of a quality not obtainable by earth-based technology. The "Korund" has a microcomputer which enables any program to be selected within the framework of the technological process, after which all 12 capsules are treated automatically, without the participation of the cosmonauts. We have obtained the first specimens of cadmium sulphide and indium phosphite. We brought them to earth and they will be used in experimental instruments in the electronics industry.

Besides this, during this work, which is very important, the level of various disturbances and their distribution throughout the volume of the station were measured with the aid of special sensitive transducers. This will make it possible to assess the influence of microdisturbances on the course of the technological process in weightlessness.

The second group of experiments of which I wish to speak is the biotechnological group. The experiment "Tavriya" was devised by Crimean scientists and scientists and students of the Moscow Bauman Higher Technical School helped create the apparatus. The aim of the experiment is to use the electrophoresis method in weightlessness to obtain highly pure biologically active substances. The experiment on Salyut-7 was carried out for the first time during the visiting expedition of Leonid Popov, Svetlana Savitskaya and Aleksandr Serebrov. At that time, the preparations themselves were not intended to be returned to earth. The crew took back only video recordings of the process and photographic material which made possible a complete assessment of the basic parameters: the efficiency of the process, the degree of purity achieved and the productivity. Our crew continued the research by a more precise method. The preparations themselves have now been returned to earth.

As a result of the experiment it has been possible to separate albumin, one of the most valuable proteins in human blood, into five components. It is well known that various enzymes are produced in the human organism, which can themselves constitute very powerful medicines. The contemporary terrestrial technology for manufacturing active biological substances is very expensive and does not allow the necessary purity of the preparation to be obtained to avoid various allergy complications. The method developed by the Crimean scientists enabled us to obtain some components to a degree of purity 10-15 times as great as that obtainable on earth. Furthermore, the productivity in a number of cases is several hundred times that on earth.

The biotechnological experiment group also includes the "Gel" experiment, the aim of which is to study the particular characteristics of the formation of gels in conditions of weightlessness. The results of this experiment could be of significance both to fundamental biology and for biotechnology. All this opens up the possibility of obtaining in orbit pure biologically active substances that cannot be produced by terrestrial technology. Such substances may be used in pharmacology, microbiology, genetic engineering and agriculture. We are sure that space biotechnology will be developed further and will become a real space industry.

During the flight the crew carried out a great number of astrophysical experiments. Within the framework of the Soviet-French national programs, astrophysical and geophysical objects were photographed by the "Piramig" and "PCN" equipment. New data were obtained on the distribution of cold stars in the nearest galaxies, the polarization of zodiacal light in the infrared range and the fine structure of the emission layers. For the first time, space photographs were taken of the hydroforce waves of the Austin comet, and we believe we succeeded in registering plankton field currents in the ocean. The high quality of the photographs of astrophysical objects was possible due to the precise alignment and stabilization of the station. Furthermore, during the process of exposure, stabilization cannot be carried out by the engines because the flare could fade the phtographs. The Popov, Ryumin crew proposed a method for precise alignment by small impulses. We used it for the alignment and stabilization of the station, and in doing so we refrained from switching on the alignment engines during the exposure of film. This method made it possible to carry out alignment with a precision of up to 2-5 minutes of arc, which in terms of angular velocities is approaching one fifty-thousandth of a degree a second, and to obtain high-quality photographs of stars down to stellar magnitude 12.5

Synchronous observations are of great interest: we studied X-ray sources together with land-based observatories. In the station we carried out research in the X-ray band and the land-based observatories covered the optical and radio zones. On board the station this was done using the RT-4M X-ray telescope and the SKR-02M X-ray spectrometer. The results are being processed, but we can already say that interesting data have been obtained about a powerful flare-up of X-ray source NJC-41-51, which was several times greater than the average. The X-ray spectrometer was used to study about 20 sources in the constellations of Cygnus, Scorpio and Sagittarius. Here I would like to make particular mention of the wide use of the Delta system in checking and controlling the station. This system includes a computer and its utilization increased the station's dynamic possibilities and to a considerable extent relieved the crew. Only with its aid were we able to carry out such an amount of astrophysical research. As you know, photos using the "Piramig" and "PCN" cameras are taken with the station on the shadow side of earth. The apparatus has to be switched off before the station comes into the light, quickly, and in accordance with an arranged program. Having aligned the station first with one source, then by the shortest route for saving fuel and time--which is very important--it was aligned with a second source and then a third. In this way, during one shadow-period we had time to photograph three sources. It would not have been possible to do this by manual alignment. Another great advantage of the system, besides this, is that its mathematical input facilities make it possible to feed in new programs during the flight. As a result of cooperation between the crew and the developers, a number of new routines were fed in, taking account of the most important requirements for conducting experiments. For instance, we were able to determine the station's position in space so that, without assistance from the earth, we could turn the station from any random position to a set position. As well as this, using a special viewer we were able to determine the coordinates of terrestrial objects: forest fires, geological structures, and so on.

During the flight, the crew worked out a method of combined operation with the Delta system which considerably changed the nature of work on board the station, relieving the crew of many ancillary operations connected with controling the station and some of the scientific apparatus.

The program of biological experiments included research using the following installations: "Magnitogravistat," for studying the cultivation of seeds in a nonuniform magnetic field; "Biogravistat," with various gravity-acceleration forces; "Oasis," and the devices "Vazon" and "Svetoblok." The main result was that the possibility of a full cycle of the development of plants in space flight conditions was proved. In the "Fiton" device where seeds of a sample plant arabidopsis were planted, for the first time, about 200 seeds were obtained in orbit and returned to earth. Some of these have already been planted and the first shoots have come up. In the "Oasis" system we grew peas, wheat and oats, but so far, unfortunately, we have not managed to obtain any seeds. We also had, as you might say, our own private plot, which was given the name "Orbita." From seeds which were on board we grew ten varieties of different agricultural crops: radishes, borage, onions and various lettuce-type plants. I would like to mention that the biological experiments are not only of scientific significance, but also of psychological significance. It is amazingly pleasant on board to look after plants and to observe them. I think that in future long flights there will be a lot of plants. They are simply essential to man in space.

During the flight, a large program of technical experiments was also fulfilled. We were checking new instruments and perfecting them. We also studied means of control and the dynamic characteristics of the complex. Using a mass-spectrometer, the composition and dynamics of the atmosphere surrounding the station were found. It proved to be denser than was supposed. Knowing its characteristics will make it possible to assess its influence on the functioning of the station's apparatus and on the conduct of experiments.

A spacewalk took place on the 78th day of work in orbit. This lasted 2 hours 33 minutes. We devoted much effort and time preparing for this on earth. The preparation was thorough. During preparations for the spacewalk, the spacesuit systems and the airlocks worked without failures. The crew felt fine and well capable of work. We dismantled and brought into the station an instrument for registering micrometeorites, panels with biopolymers, optical and structural materials, rubber seals, fiberglass and carbon-plastics, and insulating coatings which had been outside since the station was put into orbit. In their place we fitted new ones--altogether about 20 specimens of different materials which in the future will be used in space technology. Now these materials are continuing to be tested in space conditions, the simulation of which is very difficult, and sometimes impossible, on earth. Therefore, there is no doubt that open space will continue to be used as a natural laboratory.

Taking into account that one of the main forms of human activity in space in the near future will be the assembly of large structures, we carried out technological operations, the aim of which was to assess the effectiveness of using thermomechanical and threaded joints of various pairs of metals, to assess tools and the capability of cosmonauts to carry out assembly work in orbit. During the spacewalk we continued to test the spacesuits, which are now more sophisticated, reliable and convenient than those in which the Salyut-6 crews worked.

I should like to dwell on one interesting technical experiment. For the first time in manned space flight, the satellite "Iskra-2" and "Iskra-3" were launched from on board the station. It is particularly pleasant for me, as a former Moscow Aviation Institute student, to be able to say that they were developed in the students' design bureau there. For the first time in the world, amateurs communicated by shortwave radio with the aid of a relay unit on board the "Iskra-3" satellite.

The youth organizations of the socialist countries took part in the work with the satellite. This program of joint work was given the name of Student Intercosmos. It is gratifying to note that the students of our colleges can now carry out such complex work. This considerably consolidates the students' knowledge and enables them to adapt more rapidly to practical work. I think this sort of work should be continued.

Much attention was devoted to visual observations during the flight which are especially important on prolonged flights. For us this was both a rest from the everyday life on the station and it was major work which gave immediate returns.

There was a little specialization in our crew--Anatoliy dealt more with agricultural problems and I dealt with geology. We saw the possibility here of immediately providing something specific for the country's economy to repay our space flight, speaking figuratively.

It is very pleasing that even during the flight, six geological parties worked from our reports and confirmed our information: a gas deposit has already been found in the Caspian region and water reserves have been found in Kazakhstan. We managed to confirm geologists' suppositions about many areas. For example, about the territory of the BAM and Central Asia and about fractures in the Ukraine.

On instructions from agricultural specialists, observations were made of rural regions stituated mainly in Krasnodar Kray. Here we had to resolve three tasks: to determine the dynamics of the development of agricultural crops from spring shoots to ripening crops, to determine the possibility of seeing diseased areas of plants by a change in color, and to assess erosion processes. One may say that all these tasks can be resolved from orbit.

Seventy-eight reports were passed on to oceanologists, geologists, meteorologists and agricultural and forestry specialists as a result of the crew's visual observations. About 20,000 photographs of our country were brought to earth made with handheld cameras and the stationary cameras MKF and KT-140, the MKF working in six zones of the spectrum. This covers more than 200 million square km, or one-quarter of the area of the earth.

To complete my statement I should like to thank all those who built the station, the spacecraft and the apparatus for our work in orbit and all those who developed the experiments and those on earth who constantly helped us to carry them out. I would like to thank the artists and journalists who were in touch with us and all our people whose support we felt throughout those 7 months.

Our flight was dedicated to a remarkable jubilee, the 60th anniversary of the USSR. It was a true reflection of the immense achievements of our socialist society in all spheres of life and activity. We view all that we have done as a humble contribution to the common cause of our people. Thank you for your attention.

CSO: 1866/76

'KORUND' CRYSTAL PRODUCTION UNIT ON 'SALYUT-7'

Moscow SOTSIALISTICHESKAYA INDUSTRIYA in Russian 7 Dec 82 p 4

[Article by V. Zubkov, SOTSIALISTICHESKAYA INDUSTRIYA correspondent, from Flight Control Center]

[Text] After hearing the last instructions of specialists over the loudspeaker Valentin Lebedev stated:

"Well, we are opening our plant and beginning semi-industrial production."

To be sure, here he allowed some exaggeration, but it was by no means Utopian. The "Korund" apparatus, with which the cosmonauts began to work aboard the "Salyut" in essence is semi-industrial. And the onset of its operation is a significant event in the field of space technology: it throws a bridge between experiments in orbit to the production of crystals in space.

The customary progressive development of technology -- from [illegible] simple to the complex -- for the time being is not impaired here. The "Korund" is more complex than its predecessors, the "Kristall" and the "Magma," operating earlier, including during the time of the Soviet-French expedition. But now the industrial apparatuses which are being raised into space on its heels will be far simpler.

The following question can arise: why in general is the production of crystals in space necessary? From the time of the appearance of the first transistor, the development of semiconductor technology has proceeded along the path of an increase in their size. And since the appearance of integrated circuits -- along the path of an increase in the degree of integration -- an increase in the number of elements in one crystal. Only due to the appearance of so-called integrated circuits, where hundreds of thousands of elements are placed in a square millimeter, has it become possible to create modern computers and microprocessors, resulting in a qualitative jump in technology.

But an insoluble problem has arisen before the creators of semiconductor technology. The large crystals which were required for integrated circuits and lasers, receiving and transmitting equipment, proved to be nonuniform, with structural defects. And it is well known that where something is thin it will break. Applicable to semiconductor technology, where there is a structural defect there is also a failure. In high-current systems, such as in the electrical apparatus of electric locomotives, where there is a high voltage and great currents, so-called avalanche transit time diodes malfunction primarily due to inhomogeneities of the material. But in solid-state television tubes (vidicons), where the target is made of a semiconductor material, due to the excess of heat forming in places with an inhomogeneous structure this target is destroyed.

How does a homogeneous crystal grow? What physical phenomena are responsible for one structural element being dissimilar to the other? It was not simple to answer these questions. Convective processes and gravitational forces which cannot be avoided on the earth "blurred" the entire picture. It appeared that weightlessness conditions make it possible to solve these problems. And in orbit experiments were carried out for the cultivation of crystals and the melting of materials with different specific gravities. But initially these experiments were carried out using schemes and regimes perfected on earth. And they did not give the desired result.

The problems did not decrease in number. And at times their number even increased.

"The principal tasks of the experiments with the 'Korund' were obtaining new data for creating the principles of experimental-industrial production in orbit," says V. Khryapov, director of the technological experiments with an apparatus of the 'Elektronika' series, which includes the new apparatus. "Two types of similar apparatus are known today in both Soviet and in foreign practice of cosmonautics. In some an ampule with a sample moves through the heating zone. In others the ampule is fixed in position and the heat field moves. Each of these methods has its shortcomings and advantages. The former apparatuses operated on one of these principles. Their shortcoming was that several regimes were incorporated into these furnaces. And the cosmonaut could only alternately activate them, not being able to change them. In the 'Korund' we have matched both methods; here both the ampule and the heat field can be moved. Moreover, this field is created by three heating elements operating under independent programs."

The technological experiments carried out in space made it possible to come closer to a clarification of the nature of the growth of crystals, the mechanism of the transpiring processes, the perfecting of schemes for technological processes for obtaining different compounds.

Although the samples of indium antimonide and cadmium selenide obtained with the "Korund" are finding application in real instruments, nevertheless it is intended for research work. And microcomputers of the "Elektronika" series, entering into this apparatus, make possible maximum automation of experiments: they can be carried out even at a time when there is no one on the station.

As noted by V. Khryapov, "for the experimenters this variant is even preferable: when there are no cosmonauts on the station and only a few of its systems are operative the noise is less and is different, exerting an influence on the purity of the experiments. For operation in an autonomous regime provision is made in the 'Korund' for units of the revolver type into which 12 containers with samples are charged. By command from the earth these containers can be fed into the working zone, where they are heated and cooled in the most different regimes. Upon completion of the experiment, which can last up to 68 hours, one capsule is removed and the other replaces it."

"Now for some figures. The diameter of the ampule is 30 mm. The length is 30 cm. If the process is perfected, from the 12 containers it is already possible to obtain a substantial quantity of production."

Photograph of "Korund" industrial apparatus.

In their time the flier-cosmonauts stated that in the long run it is possible to anticipate the creation of special technological modules which will be docked to stations similar to the "Salyut." There is no doubt that the apparatuses which will be carried in these modules will become 'children' of the "Korund."

In short, Valentin Lebedev, in saying that a factory will be opened in orbit, although he spoke in haste, it was not by much.

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CSO: 1866/40

SHATALOV INTERVIEWED ON SALYUT PROGRAM

PM241551 Moscow PRAVDA in Russian 15 Dec 82 p 3

[Interview by V. Gubarev with twice Hero of the Soviet Union V. A. Shatalov, chief of Soviet cosmonaut training: "The El'brus's Orbits"]

[Text] "We do not fly for the sake of records," Shatalov objected. He frowned; obviously Vladimir Aleksandrovich often has to answer such questions.

I had unwarily asked how he viewed the record endurance flight of Anatoliy Berezovoy and Valentin Lebedev. I had stressed the word "record."

"For each mission we have a well-defined work program. That is the main thing. But if a space record is set in the course of a flight then it goes down as one of the results. It is easy to convince yourself of this with the example of Anatoliy and Valentin. To overtake the achievement of V. Ryumin and V. Lyakhov, whose flight lasted 175 days, it was necessary to fly for 193 days, and that would have been sufficient to set a record. Berezovoy and Lebedev worked in space for 211 days--as many as were required to carry out the flight program."

[Question] It is now particularly strikingly clear that it was very complex and extensive....

[Answer] It has been a really intense but also very interesting year, V. A. Shatalov said. The new Salyut-7 station was put into orbit. It constituted a new step forward in cosmonautics. Although the station does not differ externally from the previous, already illustrious Salyut-6, internally it was changed. The experience of Salyut-6's extended missions was taken in account. The crews made a number of observations to the designers, and we succeeded in implementing many of them.

[Question] Berezovoy and Lebedev regularly occupied themselves with so-called 'technical experiments'....

[Answer] By this we mean the testing of various of the station's systems and design features as well as the replacement of a number of units with new ones. They were delivered by Progress cargo craft. Thus, in the first stage of the flight the principal task set Anatoliy Berezovoy and Valentin

Lebedev was to master the new station in flight. A great deal, primarily the extended operation of Salyut-7, depended on their work in the first month. The cosmonauts carried out this task marvellously and ensured the reception and normal working of two visiting missions, including the Soviet-French one.

[Question] Both sides' scientists who prepared the scientific program are satisfied: Four Soviet cosmonauts and Jean-Loup Chretien not only carried out the planned research but also managed to repeat a number of experiments.

[Answer] In point of fact we managed to extend the Soviet-French flight, V. A. Shatalov noted. Following the return to the earth of V. Dzhanibekov, A. Ivanchenkov and Jean-Loup Chretien the 'Elbruses,' with the help of equipment made in France, regularly carried out studies of the Earth and outer space, and subsequently, during the work in the orbital complex by the crew consisting of L. Popov, A. Serebrov and S. Savitskaya, we succeded in refining and developing many observations made by the first visiting crew. In this way, three missions, a main one and two of short duration, implemented a comprehensive, international program, interest in which was exceptionally wide not only in the USSR and France but in many countries in the world. I would like to note that the cosmonauts carried out a number of experiments proposed by scientists of socialist community countries. The international program begun on Salyut-6 is being successfully implemented--you know that on board Salyut-7 there is to be found equipment and instruments made also in countries taking part in the "Intercosmos" program.

[Question] During the flight the experiments and research carried out by Berezovoy and Lebedev were talked about in detail. One of the scientists following their flight observed that one cosmonaut's day is a month's work for us, and to analyze and generalize everything that we get back from space during a mission requires years...."

[Answer] I admire the "Elbruses'" professionalism, Shatalov said. Naturally, at the training center everything necessary is done to equip the cosmonauts with a knowledge of the various areas of science and technology, but without a profound interest in carrying out the experiments and personal contacts with the scientists it is impossible to master the complex of scientific apparatus installed on Salyut-7.

However, the first extended flights in the orbital complex have shown that the value of research increases several fold if the cosmonaut knows both the equipment and the aims of the research down to the last detail. It is no accident that it is precisely through the crews' initiatives that so much has been done for the national economy's development. During each extended space flight both fundamental scientific problems and practical tasks of the present are solved.

[Question] Berezovoy and Lebedev worked selflessly and--something of no small importance--maintained high efficiency to the very end of the flight.

[Answer] The main thing in our profession is understanding responsibility. Responsibility toward the comrades in the cosmonaut squad, toward the party and the motherland. Any sort of personal considerations or individual difficulties and doubts take not even second but last place. It is true that people with differing characters are trained for space flight. Everyone has his particularities and predilections, but the many years of training for a launch develop particular professional characteristics distinctive to cosmonauts alone. And those difficulties which he has to encounter during an extended mission nevertheless fade in comparison with the understanding of his duty and obligations and the desire to bring the greatest possible benefits to the country and to science.

[Question] "Probably, therefore, selection for the squad is exceptionally strict?"

[Answer] It is determined by harsh necessity. One man in space represents hundreds, thousands of people. And he must be reliable. Training for a specific flight now takes 3-4 years, but the prospective cosmonaut has to study for an additional 5-6 years the theory and the equipment and participate in the development of new instruments, in the creation of spacecraft and stations, in flight control and in backup. Faultless work beyond the earth is only possible when a deep knowledge of the "terrestrial space" is possessed. Berezovoy and Lebedev bore this out once again.

[Question] "This year for the first time there was a woman crew member, Svetlana Savitskaya. All the objective data show that she withstood the encounter with weightlessness very well. Is it possible to say that it has a more powerful effect upon the female organism?"

[Answer] We still do not yet fully understand weightlessness, Vladimir Aleksandrovich said with a smile. We need to continue to collect statistics. Unfortunately, the doctors are not yet able to say with absolute accuracy how weightlessness affects a specific person, whether man or woman. Sometimes during training in the simulation chamber the pilots show very good results but in space everything is different. We have not had cases of cosmonauts being out of action for 24 hours or several days, although many of them have indeed experienced unpleasant sensations. But such occurrences are frequent among the Americans. Our selection program is more rigorous. Svetlana Savitskaya's work as a member of a joint crew has demonstrated that women are able to spend much longer in space. Future stations will require meteorologists, doctors and scientists with various specialties. Consequently, women must work there on an equal footing with men. There can be no restrictions laid on them. I am in no doubt that women alongside men will carry out even extended missions.

[Question] "What in your view is the chief characteristic of the 'Elbruses'?"

[Answer] High professionalism, skill, thorough knowledge, self-control, psychological stability, kindness in their attitude to one another, an understanding of responsibility....and, naturally, courage.

[Question] As the cosmonaut training leader are you satisfied with the past space year?

[Answer] The country is celebrating the 60th anniversary of the USSR's formation. Soviet cosmonauts are devoting all their strength and knowledge on behalf of our motherland's prosperity. Much has been done, but quite a lot of the tasks set at the 26th party congress still have to be solved. And that is why today we are not only summing up results but chiefly thinking about the future. So, we must work, and for the cosmonauts that means training for future launches.

CSO: 1866/75

MANNED 'SALYUT-6' FLIGHTS UNDER INTERCOSMOS PROGRAM

Moscow ZEMLYA I VSELENNAYA in Russian No 2, Mar-Apr 82 p 14

[Unsigned article]

[Text] Four years of successful operation of the "Salyut-6" orbital scientific station ended on 29 September 1981. The station completed 23,030 orbits around the earth on that day at 1330 hours Moscow time. In that time the scientific research program, five primary expeditions and 11 visiting expeditions were successfully completed on the station. The manned operating time of the station was 676 days. It made 35 dockings with manned and automatic spacecraft and three cosmonauts took space walks.

The station crews carried out a broad experimental research program and obtained valuable information which will find application in various areas of science and engineering.

The experiments and research performed on manned flights under the "Intercosmos" program played a significant role in the work done on the "Salyut-6" station. The work was participated in by the primary crews working on the station for prolonged periods (Yu. V. Romanenko, G. M. Grechko; V. V. Kovalenok, A. S. Ivanchenkov; V. A. Lyakhov, V. V. Ryumin; L. I. Popov, V. V. Ryumin; V. V. Kovalenok, V. P. Savinykh), and the visiting crews: A. A. Gubarev, V. Remek (Czechoslovakia), the "Soyuz-28," 3 to 10 March 1978; P. I. Klimuk, M. Germashevskiy (Polish People's Republic), "Soyuz-30," 27 June to 5 July 1978; V. F. Bykovskiy, Z. Jen (German Democratic Republic), "Soyuz-31," 26 August to 3 September 1978; N. N. Rukavishnikov, G. Ivanov (People's Republic of Bulgaria), "Soyuz-33," 10 to 12 April 1979; V. N. Kubasov, B. Farkash (Hungarian People's Republic), "Soyuz-36," 27 May to 3 June 1980; V. V. Gorbatko, Fam Tuan (Socialist Republic of Vietnam), "Soyuz-37," 23 July to 31 August 1980; Yu. V. Romanenko, Arnold T. Mendes (Cuba), "Soyuz-38," 18 to 26 September 1980; V. A. Dzhanibekov, Zh. Gurragcha (Mongolian People's Republic), "Soyuz-39," 22 to 30 March 1981; L. I. Popov, D. Prunariu (Romania), "Soyuz-40," 14 to 22 May 1981.

In the articles published below in conjunction with Cosmonauts' Day, the scientists tell about four basic areas of research performed during manned flights under the "Intercosmos" program.

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SPACE PHYSICS STUDIED IN INTERCOSMOS PROGRAM

Moscow ZEMLYA I VSELENNAYA in Russian No 2, Mar-Apr 82 pp 15-20

[Article by candidate of physical and mathematical sciences V. M. Balebanov and candidate of physical and mathematical sciences A. V. Zakharov]

[Text] The manned flights under the "Intercosmos" program became a logical continuation of the program which was begun at the end of the 1960's. Space physics played an important role in the research. In past years, work has been done in this field on 20 satellites of the "Intercosmos" series, 10 "Vertikal'" rockets and also on several "Prognoz" satellites launched under the Soviet national program. The primary areas in which experiments were conducted were the physical processes in the ionosphere, the earth's magnetosphere, and interplanetary space, the sun and solar activity, and cosmic radiation.

The insertion of a measuring probe into a medium, the properties of which are to be studied is one of the basic methods of research in the field of space physics. However, a number of restrictions immediately arise: namely, such equipment must be electrically neutral, nonmagnetic, in order not to change the electromagnetic characteristics of the environment, not release gases, not emit waves during wave and plasma measurements, and have minimum dimensions. The indicated requirements are best satisfied by small automatic earth satellites (of the "Intercosmos" satellite type) and probes that are launched into interplanetary space (equipment of the "Prognoz" type). However, there are physical phenomena which cannot be investigated, using only small automatic satellites. These include radiation from distant astronomical objects in a wide range of wavelengths and the high-energy component of galactic cosmic radiation. For this purpose either multiton automatic units or manned spacecraft are inserted into orbit. Also, in order subsequently to create the optimal automatic instrument, it is desirable to trust man with the performance of the first experiments. The research cosmonaut has worked on the manned station in such cases.

The study of optical phenomena in the upper atmosphere--the polar auroras, the middle latitudinalred arcs and equatorial glow--played a significant role in the manned part of the "Intercosmos" program.

Polar Auroras

The polar auroras encompass a number of magnetospheric and geophysical phenomena. One of them is the glow of the upper layers of the atmosphere in the polar regions which is visible to the naked eye. It occurs when high energy charged particles from the earth's magnetosphere penetrate the ionosphere and atmosphere.

The optical glow of the atmosphere can also be observed at low latitudes. In particular, the glow of the upper atmosphere in the vicinity of the equator is of great interest. This glow is connected with significant reduction in plasma concentration (ionospheric inhomogeneities) over the geomagnetic equator.

In middle latitudes another class of atmospheric glow is observed--"stable auroral arcs." Studies by the "Intercosmos-2, 8 and 12" satellites provided information about the distribution of equatorial and middle latitudinal inhomogeneities in the ionospheric plasma. However, there is still very little data received from space on the optical phenomena in the ionosphere.

During powerful geomagnetic disturbances and magnetic storms accompanied by auroras, radio communications can be disrupted, interference appears in radar systems, telegraph and telephone networks. Therefore, the study of phenomena connected with atmospheric auroras has great practical value--for possible prediction of such interference, a discovery of its nature and characteristics.

The basic material during the course of investigation of the optical emission of the upper atmosphere and, in particular, the polar auroras came from ground visual and photographic observations. However, an observer on the ground is capable of seeing only a small part of the polar auroras, the part which is concentrated in the oval zones around the magnetic poles where weak auroras are observed almost constantly. The complex ionospheric-magnetospheric processes are most conveniently studied from on board a manned spacecraft inasmuch as visual observations from an orbital station permit a remarkable part of the polar aurora oval to be encompassed visually with great simplicity.

The "polar aurora" experiment performed on board the "Salyut-6"-"Soyuz-29"-"Soyuz-31" orbital complex manned by an international crew with the participation of German Democratic Republic cosmonaut Z. Jen, included a description (in accordance with the previously developed "questionnaire" in the flight log) of the form of the polar auroras, their color and intensity. The observations were accompanied by drawings in the log and a recording on a dictation machine. In case of stationary and slowly moving auroras, the altitudes of the upper and lower boundaries of the individual sections (with indication of each altitude on the drawings), the extent of the auroras azimuthally and also the distance of them from the orbital station were estimated. Sometimes shifts of the auroras were noted, and their velocity was estimated.

The description of the auroras provided by Z. Jen follows: diffuse shapes and arcs were usually observed, sometimes uniform, sometimes radiant. Here individual beams change their position and altitude. The auroras had a gray green color. The estimate shows that the brightness of the auroras did not exceed 2 (an aurora of brightness 1 corresponds to a brightness equal to the brightness of the Milky Way; many colors have already been distinguished in brightness 3 auroras).

On 1 to 2 September 1978, the cosmonauts recorded polar auroras over Australia. The best conditions for observing the oval of the polar aurora came in this part of the world at the end of August and the beginning of September 1978 in the early morning hours. At that time usually uniform aurora shapes were replaced by weak radiant arcs and bunches of rays. The drawings in the flight log corresponded fully to the existing concepts.

After Z. Jen's flight, many reports came in on observations of the aurora from the "Salyut-6" station. Usually these were quiet auroras visible on the horizon. However, when the station went inside the auroras, fine details and also a variety of colors became distinguishable (the reports by A. S. Ivanchenkov in 1978). Flight inside an aurora is capable of providing a great deal of information about the fine structure of individual forms of the aurora, the diameters and flashes of the rays and distances between them, the degree of their uniformity, the presence of individual jets in them and color variation. Specialists can study the nature of the interaction of particles coming in from the magnetosphere with the upper atmosphere of the earth. Regular visual observations of atmospheric auroras were also started, and it can be stated that they are making a significant contribution to the understanding of the processes occurring in the earth's magnetosphere.

"Duga" Investigates

Another method of investigating optical emissions in the earth's upper atmosphere from on board a manned orbital station is electrometric measurements of the glow of the upper atmosphere and also the search for middle latitudinal red arcs. These studies were performed using the "Duga" electrophotometer built in the People's Republic of Bulgaria for the scientific research program with the participation of a Bulgarian cosmonaut. The experiments with the "Duga" were continued by the Soviet-Vietnamese crew.

The "Duga" consists of two modules: the opticomechanical module and the data recording module (with digital tape recorder). The basic elements of the opticomechanical module include the optical telescope, dispersing system and image converter. The dispersing system was developed on the basis of four rocking light filters. The instrument measures the intensity of emissions with a wavelength of 6300, 5577, 4278 and 6563 angstroms. For optical observations in the electrophotometer, a meniscus telescope reflector of the Cassegranian system was used. A viewer was located parallel to the optical axis of the telescope permitting the cosmonaut operator to aim the instrument at the investigated phenomenon. The instrument was attached to the station window by means of a flange.

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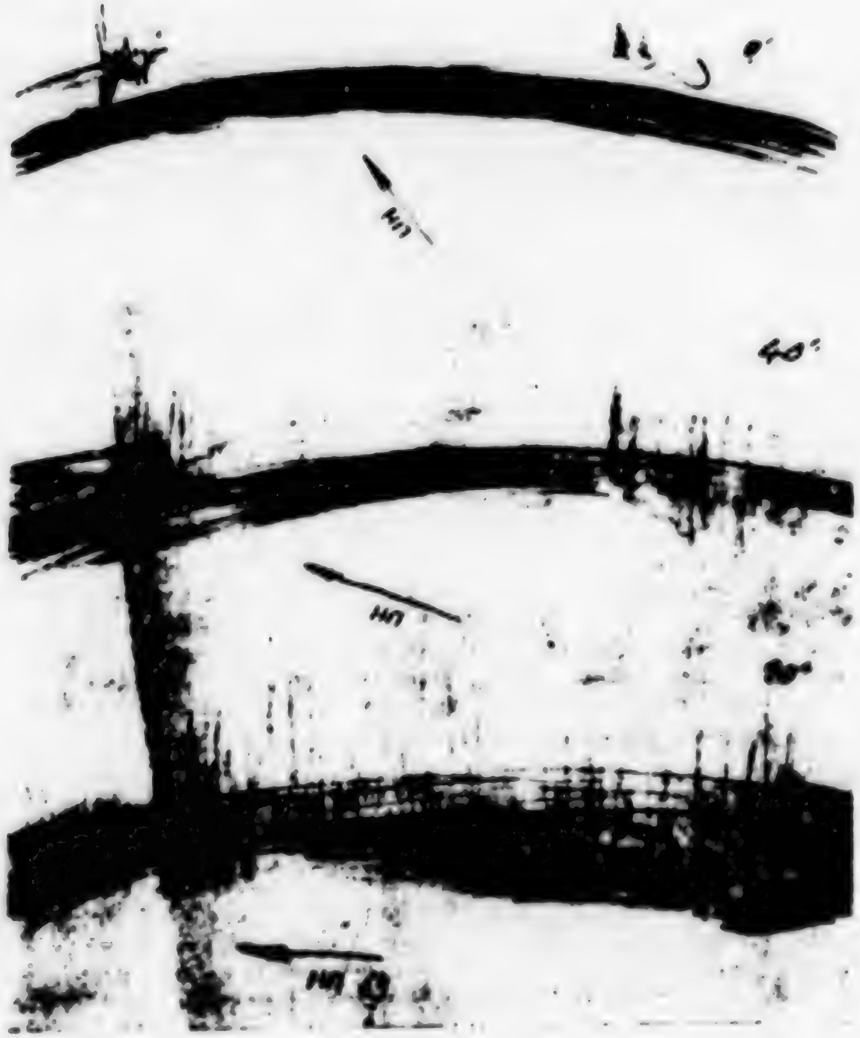


Sketches of polar auroras made on 1 and 2 September 1978 on orbits 5331 and 5332 of the "Salyut-6" station during joint space flight of USSR and GDR Cosmonauts

Key:
1. Orbit

Key:
1. Orbit

One of the basic experiments performed on the orbital station with the "Duga" instrument was the "Ekvator" [equator] experiment. In this experiment a study was made of the equatorial optical phenomena in the ionosphere for discovery of their physical nature. The instrument recorded the equatorial arcs. The intensity was 10 times higher than outside the equatorial region. The brightest emission in the arc was the red oxygen line with a wavelength of 6300 angstroms. In addition to the red line, glow of the green line with a wavelength of 5577 angstroms was also detected. The intensity of its emission was also 4 to 6 times less than red. Emissions with a wavelength of 4278 and 6563 angstroms were not recorded. It must be noted that the line with a wavelength of 4728 angstroms is connected with outpouring of electrons, whereas the line with a wavelength of 6563 angstroms is connected with outpouring of protons. Consequently, the outpouring electron and proton fluxes are very small and cannot explain the equatorial glow. The results of measuring emissions with a wavelength of 6300 and 5577 angstroms have important significance for discovering the nature of red arcs. The ratio of the intensities in these lines (4 to 6) obtained during the course of the experiment indicates that the glow in the given region basically takes place with recombination of molecular oxygen ions. It follows from this that the equatorial arcs occur when the plasma of the F-region moves downward (ZEMLYA I VSELENNAYA, No 5, 1981, pp 42-46--Ed.). This conclusion is the basic result determining the mechanism of the formation of equatorial glows. The first results of Soviet-Bulgarian research have already been summed up and published in the "Reports of the Bulgarian Academy of Sciences."

"Polyarizatsiya" [Polarization], "Izlucheniye" [Radiation], "Astro" Experiments

Another experiment based on visual observations from on board a manned ship (station) is the "Polyarizatsiya" experiment. This experiment was performed by an international crew with the participation of cosmonauts from the German Democratic Republic, Hungarian People's Republic, Socialist Republic of Vietnam and Mongolian People's Republic.

In the "Polyarizatsiya" experiment a study was made of how the polarization of sunlight changes on dispersion by the atmosphere and reflection from the earth's surface. This is very important in atmospheric optics for determination of the properties of the atmosphere, for meteorological research, the discovery of natural resources of our planet.

In contrast to the polarization observations of the atmosphere from the earth's surface already performed for more than 70 years, studies from space have incomparably greater scope. Therefore it is necessary to consider variation of the landscape--to photograph the observed atmosphere-landscape situations in parallel.

Portable polarimeter used in the "Polyarizatsiya" experiment

The polarization studies from space are at the present time in the stage of accumulation of statistical data. In addition, the results of each "Polyarizatsiya" experiment performed by different crews of the "Salyut" station help to refine the procedure for performing the experiment, and, the main thing, they promote improvement of the structural design of the instrument which, according to the designs of its creators, can automatically take into account the optical properties of the atmosphere during remote studies of the natural resources of the earth from space.

Cosmic rays were the object of the "Izlucheniye" and "Astro" experiments performed during the flights by cosmonauts from the Mongolian People's Republic and Romania.

In the vicinity of the earth, the movement of charged particles of cosmic rays is influenced by the magnetic field of our planet. The fact is that low energy particles are deflected by this field and cannot reach the earth. For example, the region where the orbit of the "Salyut" station lay cannot be penetrated by atomic nuclei of primary cosmic radiation with an energy on the order of tens of megaelectron-volts per nucleon. Nonetheless, during the flight of the American "Skylab" station, such particles were detected quite unexpectedly in this part of terrestrial space. The question of from where and how they got there requires further experimental research and theoretical explanation.

The "Izlucheniye" and "Astro" experiments were primarily aimed at studying atomic nuclei with an energy of tens of megaelectron volts per nucleon. In both experiments dielectric detectors were used to record the atomic nuclei. Heavy atomic nuclei of cosmic radiation hitting this detector damage its structure on its path of movement. If the detector is treated after the experiment using a special process (irradiation by ultraviolet radiation and pickling in an alkali solution), then microscopic tunnels and craters appear at the points of transmission of the charged particles, the parameters of which permit determination of the charge and energy of the nuclei recorded by the detector.

In the "Izlucheniye" experiment, a combination of different dielectric detectors was used, the basic part of which was lavsan. Mica and polycarbonate films were also used as detectors. The gear created jointly by specialists from the Physics and Engineering Institute of the Mongolian People's Republic Academy of Sciences and the Scientific Research Institute of Nuclear Physics of Moscow State University, consisted of two instruments.

One instrument, with a recording area of 10×16 cm^2, was designed to record particles with an energy of tens of megaelectron volts per nucleon. During the flight it was placed in the lock of the "Salyut-6" station and was exposed in open space. The second instrument was located inside the station and was designed to record atomic nuclei with an energy of several hundreds of megaelectron volts per nucleon and also to develop methods of determining the charged particle recording time by dielectric detectors. The instrument (dimensions 10×16 cm^2) consisted of two detectors--mobile and stationary. Comparing the trails left by the charged particle in the two detectors, it is possible to determine the position of the detectors at the time of the recording, and simultaneously at the time the charged particle hits the instrument.

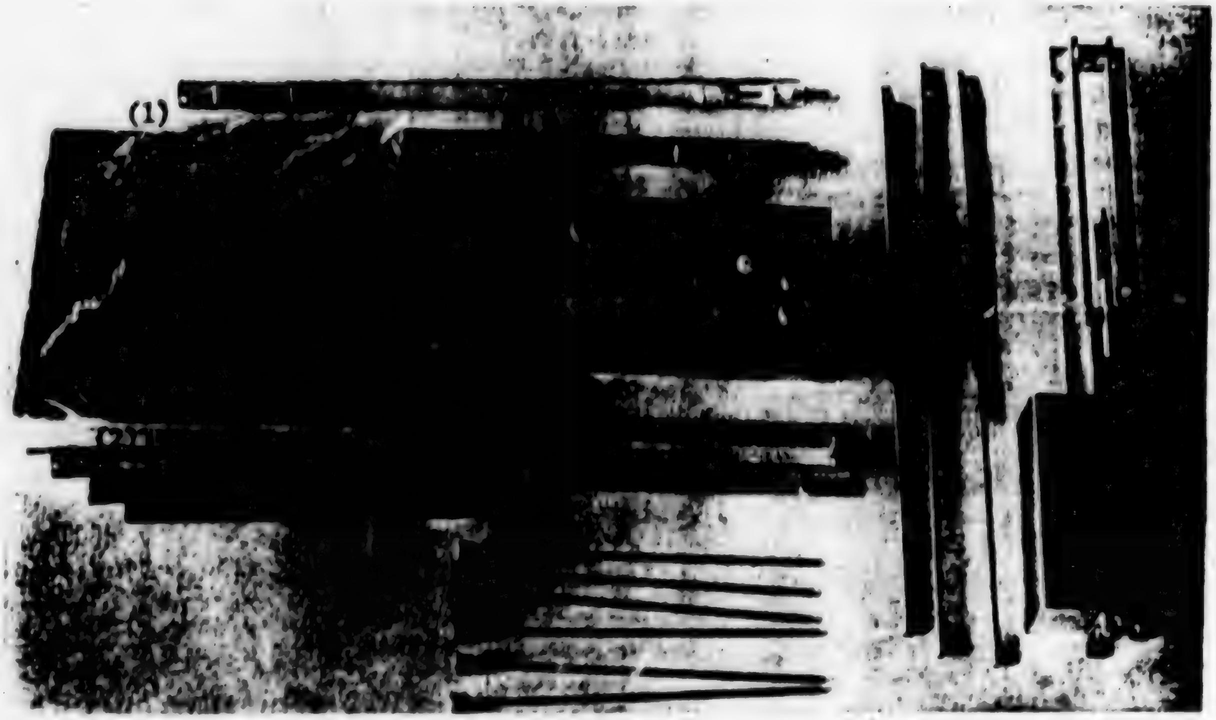
The "Astro-1" and "Astro-2" used in the "Astro" experiment were created by Romanian specialists. As the detector they contained cellulose nitrate permitting recording of nuclei in a wide range of charges. The area of the "Astro-1" instrument (during the experiment it was put in open space) was equal to 20×20 cm^2, and the area of the "Astro-2" instrument which was inside the station was 40×40 cm^2. The "Astro-2" instrument was delivered to the station in dismantled form and was assembled by the cosmonauts on board.

The detectors of the instruments used in the "Izlucheniye" and "Astro" experiments were returned to the earth, and at this time a painstaking examination of detectors to detect recorded atomic nuclei is being conducted in the Mongolian People's Republic, Romania and the USSR.

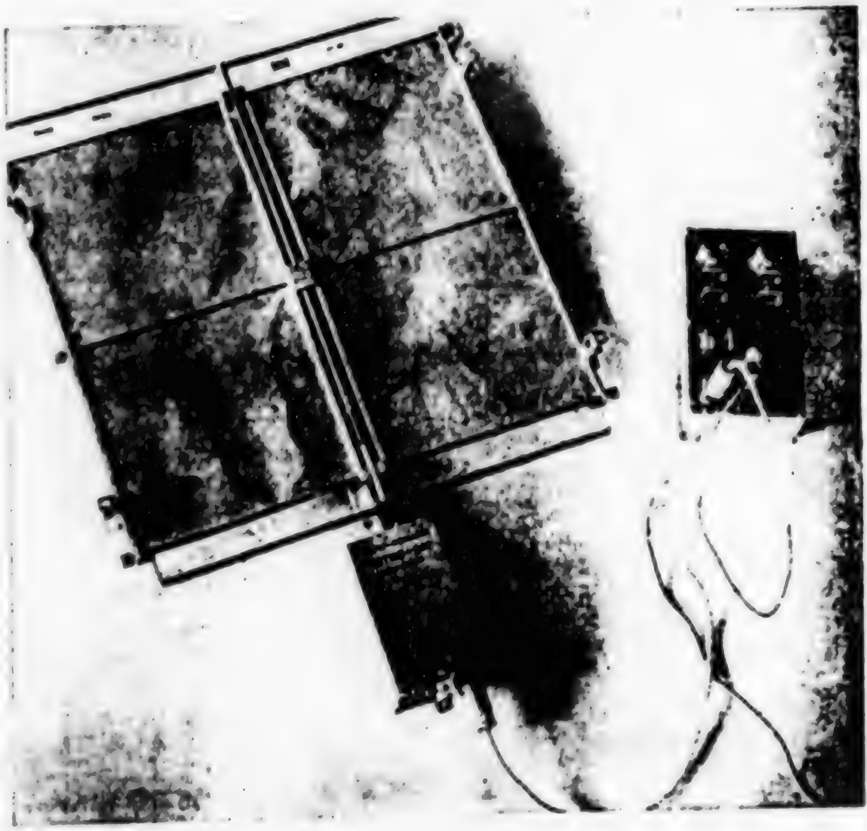
Holography in Outer Space

The "Gologramma" [Hologram] experiment prepared by Soviet and Cuban specialists and performed by the joint Soviet-Mongolian crew on board the "Salyut-6"-"Soyuz-39"-"Soyuz T-4" orbital complex is extremely interesting.

The hologram differs from photographs and television images in that it offers the possibility of creating a three-dimensional spatial image of the target. This happens as follows: a "reference" wave is directed at the photographic plate simultaneously with the "signal" wave from the same light source dispersed by the target. The pattern occurring on interference of these waves (it is called a hologram), containing complete information about the target, is recorded on a light sensitive surface. On irradiation of the hologram by the reference wave it is possible to see a three-dimensional image of the target.



"Astro-1" and "Astro-2" instruments in dismantled form.
Key:
1. Astro-1
2. Caution, do not tear foil



"Astro-2" instrument in assembled form

The problem was solved in three steps: obtaining the holographic image on board the spacecraft, transmission of the holograms over the television channel from the space station to the ground, transmission of holograms over a television channel from the ground to the station. For this purpose, the Soviet-Cuban laser holographic unit "Svet" [light] was used. It creates a holographic image of the target on the photosensitive layer of the transmitting television system. The television equipment of the "Salyut-6" station and the flight control center was also used. The targets for obtaining holograms were a sodium chloride crystal dissolved in water and the outside surface of the window of the "Salyut-6" orbital station.

The results of this experiment demonstrated that holographic means can be used in space research, in particular, to transmit a three-dimensional image, spatial relief, determine small shifts and displacement of the parts of the targets and their vibration, to record a large volume of information and realize optical processing of it. The "hologram" is at the junction of space physics, space communications and applied technical developments. Almost any area of space research is interested in further results from this experiment.

The materials from the experiments in space physics performed by international crews with the participation of cosmonauts of the socialist countries, are being processed in detail and studied by specialists. The obtained information and recommendations of the research cosmonauts provided rich material for the design of new instruments and experiments which await their realization in coming space expeditions.

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EARTH'S NATURAL RESOURCES IN MANNED FLIGHTS OF INTERCOSMOS PROGRAM

Moscow ZEMLYA I VSELENNAYA in Russian No 2, Mar-Apr 82 pp 20-28

[Article by candidate of technical sciences V. V. Arkhipov and candidate of technical sciences L. A. Ronzhin]

[Text] Research Goals

One of the main areas of manned flights under the "Intercosmos" program was, of course, the study of the natural resources of the earth. The reasons were as follows.

First, for further development of the national economy it is important to estimate the possible climate fluctuations, improve the accuracy of weather forecasts, predict earthquakes and optimize the ground communication routes. The basic thing is that it is necessary more precisely to determine the structure of the minerals of the region, discover new areas prospective for mineral prospecting.

Secondly, if we know the dynamics of the atmosphere and ocean and the structure of the mineral resources, then probably we shall be able to discover new sources of natural resources. Similarity of the elements of the geological structure of Mars and the earth is of unconditional interest. Mars has gigantic faults running thousands of kilometers analogous to earth's faults, and it has shield volanoes like the highest point of Tibesti Mountain in Africa, the extinct Emi-Kusi Volcano 3415 meters high. Yu. V. Romanenko and G. M. Grechko photographed this volcano by a portable camera from the "Salyut-6" station. Its Martian analog, the volcano named Olympus, rises 25 km above the surrounding terrain and has a diameter at the foot of about 600 km. It has the same calderas at the top of the mountain, the same fissures on the slope from lava flows, and similar shape in plan. The giant size of the volcano can be explained by the fact that signs of horizontal movements of the crust have still not been detected on Mars; as a result, the volcano was able to develop for about 100 million years.

The channels of proposed paleorivers are very similar to earth canyons. Why these valleys disappeared and why the atmosphere of the planet has almost disappeared constitute an important problem yet to be solved.

Finally, the study of the regions from space will help in the planning and implementation of international projects such as joint exploration and exploitation of mineral resources, the biological productivity of the ocean, efficient joint use of the resources of rivers flowing through the territory of several countries (let us say, the Danube), the construction of hydroelectric power plants on them, joint laying of pipelines and transportation lines, the creation of atmospheric reservations, including preservation of significant masses of forests which are "the lungs of the planet" and sources of accumulation of moisture (for example, the forests of Carpathia by the efforts of the USSR, Romania, Czechoslovakia, Polish People's Republic and Hungary), and monitoring of atmospheric, river, lake and ocean pollution.

A characteristic feature of space engineering permitting successive and periodic observation of various parts of the earth's surface of interest to scientists and economists of the participating countries favors joint observations.

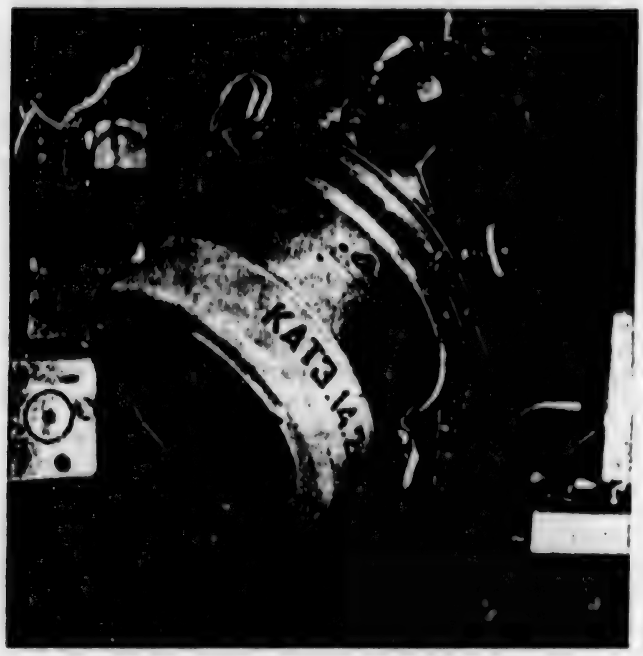
Space Photographic Engineering

During the studies of the natural resources of the earth under the "Intercosmos" program, the wide angle KATE-140 topographic camera was used which photographs black and white or spectrozonal strips more than 400 km wide from the orbital altitude of the manned station with resolution on the terrain of tens of meters.

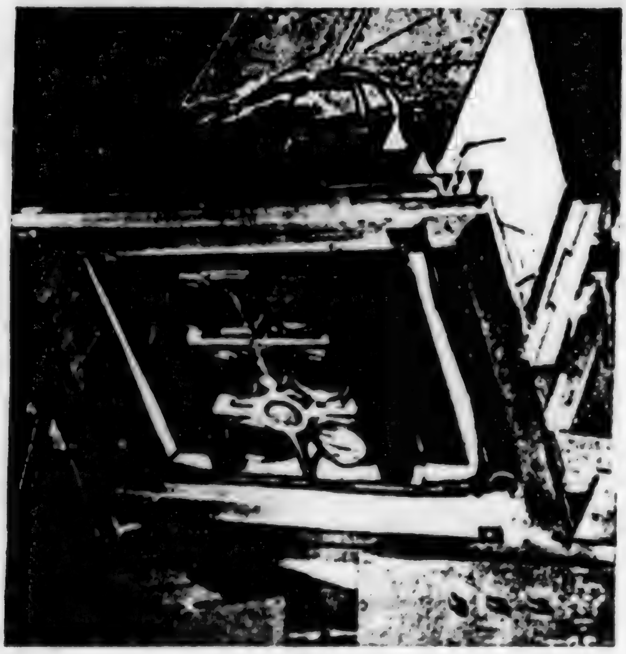
In order to study the finer characteristics of natural objects, the specialists of the USSR and the German Democratic Republic developed the multizonal MKF-6M system which covers a swath more than 200 km wide on the terrain from an altitude of 350 km with spatial resolution of tens of meters (ZEMLYA I VSELENNAYA, No 2, 1977, pp 10-15.--Ed.).

Both photographic systems were installed on board the "Salyut-6" station and were switched on by the cosmonauts on command from the earth, as a rule, simultaneously, in order to insure maximum information about the investigated objects. The operation of these stationary cameras has characteristic features. It is necessary to orient the station in space so that the optical axes of the cameras will be directed in the nadir, and orientation leads to additional expenditures of fuel. In addition, it is no accident that the station is referred to as multipurpose. The different research goals require that the station assume different positions in space. As a result, the MKF-6M and KATE-140 can be switched on only at strictly defined points in time. Therefore it is expedient to use a portable camera freely oriented in space on board the station. With such a camera the cosmonauts can document the visual observations and investigations by other portable instruments that they perform.

Although the resolution on the terrain when photographing by portable cameras is worse than with stationary cameras, these portable cameras permit objects to be photographed through the station windows at a distance of 200 to 300 km and more from the orbital path. Frequently this turns out to be sufficient, especially when solving operative problems--detection and tracking of fires, elemental disasters and accumulations of plankton in the ocean.



Medium format KATE-140 topographic camera



MKF-6 multizonal space camera

The visual and instrument research program which, beginning with the flight of the international crew made up of V. F. Bykovskiy and Z. Jen, came to be called the "Biosfera" [Biosphere] program, was supported by instruments from the German Democratic Republic, the People's Republic of Bulgaria and the Hungarian People's Republic (the "Pentakon," "Praktika" cameras and the "Spektr-15" spectrometer).

All of the crews worked closely together. Sometimes the program could not be followed inasmuch as the possibilities of the international crews in a week's stay in space were limited by the ballistic, light-shadow and weather conditions of the observation of all objects of interest.

The first primary expedition (Yu. V. Romanenko and G. M. Grechko) photographed the territory of the German Democratic Republic by the MKF-6M cameras, the second primary expedition (V. V. Kovalenok and A. S. Ivanchenkov) and the visiting expedition (P. I. Klimuk and M. Germashevskiy) photographed the territory of the Hungarian People's Republic, the German Democratic Republic and the Polish People's Republic. Subsequent crews used the stationary cameras to take joint photographs of interest to all countries participating in the "Intercosmos" program. The time the camera was switched on was selected so that as many of the previously selected targets as possible could be photographed in one pass.

The visual instrument studies under the "Biosfera" program were performed in the same way. For the international crews the specialists of the USSR and the interested country developed special flight logs containing 10 to 15 individual assignments to study natural objects and up to several tens of regions for taking photographs. These assignments were also included in the on-board documents of the primary station crews, which permitted the performance of research comprehensively and in full volume (for example, the recording of the dynamics and seasonal variations of the characteristics of the object or phenomenon).

The international crews helped each other carry out their assignments. Thus, photographing objects of interest to the German Democratic Republic was included in the flight logs of the Soviet-Cuban and Soviet-Mongolian crews, and the Soviet-Hungarian crew took photographs of Cuba. Many of the crews used the Bulgarian "Spektr-15" instrument.

Mutual assistance was also realized during ground and aircraft experiments synchronous with the space experiments. For example, scientists of the USSR, the German Democratic Republic and the People's Republic of Bulgaria participated in the "Gobi-Khangay-81" program within the territory of the Mongolian People's Republic.

Practical Results

All of the participating countries manifested the greatest interest in the problem of the geological structure of mineral resources and the shelf, the prospecting for minerals, potential sources of earthquakes and vulcanism. These problems were the subject of more than half of all of the assignments of the international crews. As is known, the probability of detecting many types of mineral resources increases sharply at points of disturbances and inhomogeneity of the earth's crust, inasmuch as the emergence of internal melts and gases is facilitated here.

As an example let us present a fragment of the Talaso-Fergan Fault (the photograph was taken by L. I. Popov and V. V. Ryumin using a portable camera). The fault is seen as a series of dark parallel stripes and as scarps of the Karatau Ridge along the edge of the Turanskaya plate which is uplifted above the plain covered with sandy deposits of the Chu-Talasskoye interfluve (in the upper part of the frame). Along this and the Karatau Fault continuing it to the northwest, there are many mineral outcrops (polymetal ores, phosphorites).

The formation in the headwaters of the Manicouagan River in Canada can serve as an example of a ring structure. The ring structure is easily distinguished as a result of the emphasizing effect of the ice cover of the two lakes--Mouchalagane and Manicouagan--occupying its western and eastern halves, and the remains of the snow cover in the depressions in the terrain. It is possible to note that large iron ore deposits are found near this region (the city of Gagnon).

Distinguishing features of the landscape help to detect in particular, oil and gas. Significant attention was also given to the search for such features, for example, the presence of salt domes formed by salt extruded in the upper layers.

During the course of the studies unexpected results were obtained. Along with the well known sublatitudinal lineaments, three lineaments of meridional orientation are also observed by the observations of L. I. Popov and V. V. Ryumin in the territory of Hungary. The Danube flows through the westernmost of them, sharply changing direction north of Budapest. Outside Hungary the river again sharply changes direction to the east. Along the central lineament to the south before the mouth, the Tisa flows into the Danube, also quite sharply changing its direction in the central course. Oil and gas deposits are territorially connected with this central lineament. Finally, the easternmost lineament is located on the border with Romania.

It was discovered earlier that Balaton Lake is somehow included in the ring structure of very significant diameter. Its northern part, where it is cut off by the Varpalota lineament is very rich in minerals.

The existing geological representations of the structure of the island of Cuba and the adjacent shoals were significantly more precisely defined by L. I. Popov and V. V. Ryumin. If we look at a map of Cuba it is obvious that the island is bent into an arc. Inasmuch as the island is quite long, 1250 km, and it is from 31 to 191 km wide, numerous faults are not excluded. Some of them are known, and others have been proposed. Observations from space indicate that Cuba is covered with a quite dense network of faults intersecting each other, especially in the western and eastern edge zones. For example, the faults from the Gulf of Guanaacabibes to the Bay of Cortez are seen visually; also, Guantanamo Bay to the mouth of the high water river of the island of Toa. The fault between the Bays of Matansasa and Cochinos, the fault between the Bay of Nipe and the Gulf of Guacanayabo, between Perros Bay and the mouth of the Sasa River known from the results of geophysical studies was also confirmed and traced farther out on the shelf. The proposed faults from Sabinal Island to the southwest and southeast were not observed.

Numerous faults were studied also in the territory of the Mongolian People's Republic. Zh. Gurragcha reported, for example, that Lake Khubsugul is located in the fault zone similar to the Baykal rift zone. V. Remek observed large faults bounding the Cheshskiy massif, and he refined the pattern of its jointing. M. Germashevskiy saw large-scale lineaments within the northern part of the Polish-German lowland. Ring structures, granitoid massifs, and salt domes were seen by the cosmonauts in Mongolia, Czechoslovakia, Cuba, Hungary and the German Democratic Republic.

The participating countries gave significant attention to the study of the earth's hydrosphere, which is so important to the national economy--the rivers, lakes and glaciers, seas and oceans. (V. V. Kovalenok participated actively in the study of the hydrosphere and the development of observation procedures and photography.) The continental waters are primarily of interest as a source of fresh water for industrial and agricultural needs. In accordance with the assignments of the specialists from Hungary, the lakes of various continents were investigated. In the opinion of B. Farkash, only two lakes have a specifically green-blue color to the water--the Hungarian lake of Balaton and Lake Balkhash in Kazakhstan. The Mongolian specialists requested more precise determination of the fresh water reserves and runoff paths in the western part of Mongolia where the glaciers of Mongolian Altay and the Khangay ridge are located and also the Bol'shiye Lakes basin with the large Ubsu-Nur, Khyargas-Nur and other lakes. The photographs revealed significant moisture reserves accumulated in the glaciers and in the still unmelted snow cover of the high mountains to the specialists. In the lower part of the frame, Lakes Ureg-Nur (surface altitude 1425 meters) and Achit-Nur (altitude 1435 meters) with well preserved ice cover can be seen in the lower part of the frame. South of Lake Ureg-Nur is the Kharkhira glacier region, and to the east the outlines of Ubsu-Nur Lake are visible through the cloud cover.

The rivers and related phenomena--floods, pollution, channel dynamics, turbidity causing debris in the lakes and seas, the role in feeding the irrigation systems and the water budget--were studied in accordance with the assignments of many countries, in particular, Hungary, the Socialist Republic of Vietnam and German Democratic Republic. The deltas and debris cones of many rivers were photographed.

As a result of the fact that the waters of the Amudar'ya and Syrdar'ya are intensely used for irrigation purposes, the Aral Sea-Lake is being drawn down rapidly. Kokaral Island in the northeastern part of the sea has become a peninsula and almost joins the Syrdar'ya Delta on the opposite bank. It is obvious that the Syrdar'ya itself does not reach the sea any more, and judging by the turbidity causing debris, the main runoff channel for the waters of the Amudar'ya has become the eastern channel. The shoals are clearly visible. Salt lakes and dried up sections of the bottom can be distinguished as white spots around the sea. The white spots in the desert are grazing areas around wells trampled down by the livestock.

The seas and oceans were primarily investigated by color characteristics which can indicate currents, upwellings, temperature and turbidity. The color atlas developed in the German Democratic Republic was used for this purpose. Some of the bodies of water were studied over the entire period of operation of the station to determine the dynamics of the variation of their characteristics. Many interesting observations were made, especially in the Atlantic Ocean and Caspian Sea by V. V. Kovalenok. L. I. Popov and V. V. Ryumin used a hand-held camera for several days to obtain information about one of the interesting regions of the Atlantic Ocean--the area where the warm Gulf Stream and the cold Labrador Current running along the coast of Canada to the southeast meet. The eddies and vortexes formed here are visible as a result of the fact that the oxygen-rich cold water has a light green blue color in contrast to the violet blue warm water. For this reason it is possible to get a good picture of the contact of these two powerful currents with partial mixing and changing of direction of the water masses. Systematic observation of the given region helps more precisely to determine its influence on weather and climate.

Determination of the pollution zones of the bodies of water is also of great interest. The first results have been obtained. L. I. Popov and V. V. Ryumin observed three oil pollution zones off the coast of Cuba, in the vicinity of Havana, Santiago de Cuba, and Cochinos Bay. Finally, our mission is connected with studying the earth's atmosphere, its dynamics and purity. Information was obtained on many cyclones and hurricanes, the paths of which lay near Cuba and Vietnam. Studies were made of dust storms, and it turned out that although they do not have a global nature on the earth, as they do on Mars, they can reach other continents. Fires were observed many times, and they can easily be seen, especially against a background of snow or water.

We have only discussed some of the results of studying the earth's natural resources obtained during manned flights under the "Intercosmos" program. The processing and analysis of the information continue.

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PRODUCTION IN OUTER SPACE IN INTERCOSMOS PROGRAM

Moscow ZEMLYA I VSELENNAYA in Russian No 2, Mar-Apr 82 pp 28-32

[Article by doctor of technical sciences S. D. Grishin and doctor of technical sciences V. V. Savichev]

[Text] About 15 years ago "production in outer space" was the prerogative only of fiction writers; serious people preferred to talk about more realistic possibilities. However, everything has changed in a short time--production experiments are being run in earth orbit.

Of course, there are still no plants and factories in orbit. However, the number of experiments is growing constantly. These include studies of the physics of weightlessness (heat and mass transfer, the mechanics of multiphasal media, phase transitions and crystallization) and the manufacture of semiconductor monocrystalline samples and obtaining new composites, optical glass... The list goes on and on.

Experiments under the "Intercosmos" program have made an important contribution to the development of this new area. These experiments were primarily set up on the "Splav" and "Kristall" Soviet electric heating elements (Zemlya i Vselennaya, No 3, 1979, pp 25-28.--Ed.). Let us mention the primary parameters of this equipment, which to a significant degree determine the choice of materials on which the space experiments were performed.

The electric heating chamber of the "Splav" setup has three zones: a high-temperature, isothermal zone, a gradient zone and low-temperature isothermal zone. It is possible to set the temperature from 400 to 990°C with an adjustment range of 10°C. The capsules with the samples are 170 mm long and 20.6 mm in diameter. Directional crystallization takes place in the gradient zone as a result of monotonic lowering of the temperature.

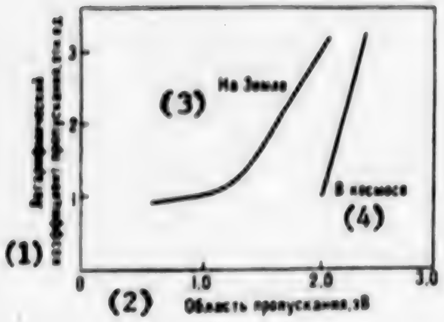
The temperature in the ampule is varied by a different process in the "Kristall" setup: the ampule with the working material is brought to a steady-state thermal zone where the temperature varies from 400 to 1200°C. The capsule is 175 mm long and 9 mm in diameter, and it passes through the hot zone at a speed of 0.188 and 0.376 mm/min. The equipment is automatically controlled.

However, this does not mean that the course of the experiment is simple and it is sufficient only to perform the necessary manipulations provided for on the ground. Flight introduces corrections. For example, the technological process of growing semiconductor single crystals with alloying additives takes tens of hours. Tens of hours of a continuous experiment... And indeed all of this time there are a number of various disturbing factors on the station which, whether we like it or not, lead to small accelerations. There is also aerodynamic braking of the station, and the operation of all possible units on board (including the orientation and stabilization systems) and vibration of the hull, and finally, simply the movement of the cosmonauts. One might think, what is so special about this? The total influence of all of these factors is so small and the acceleration is so negligible... However, whatever they may be, the forces that arise influence the course of technological processes.

The presence of small accelerations influences the heat and mass transfer in the liquid phase (in particular, convection in the melt), and this, in turn, can be reflected in the properties of the material obtained. The instruments developed by Soviet specialists have made it possible to measure the accelerations on the station under the most frequently encountered operating conditions of the station and the crew. It turned out that there is no ideal weightlessness. Accelerations depend on the operating conditions and can vary from 10^{-2} to 10^{-5} g_0 (g_0 is the gravitational acceleration on the earth's surface, g_0=9.81 m/sec^2). Even when the cosmonauts perform physical exercises on the treadmill, the accelerations increase. Under these conditions of almost complete weightlessness the cosmonauts obtained more than 20 samples under the "Intercosmos" program alone. They brought them back to earth and handed them over to the specialists. Painstaking study of the properties of the space samples began. The research process is a lengthy one; therefore at the present time only the preliminary results are known, with which we shall familiarize the reader.

"MORAVA" (Czechoslovakia)

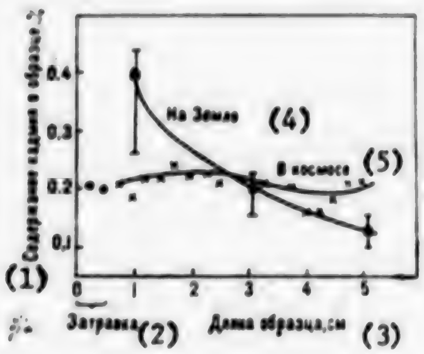
Four experiments were performed by this name with different eutectic compositions and optical materials. (The eutectic is a thin mixture of solid materials which crystallize at a temperature below the melting point of any of the components or any other mixtures of these components.) It was proposed that the way in which melts of crystalline and glass forming materials harden be studied. In contrast to earth analogs, the samples obtained on board the station turned out to be more homogeneous. The hardening of two ion compounds forming a eutectic (lead chloride and copper chloride) when one of the compounds (lead chloride) is present in excess was studied on the "Splav" device. For this purpose a mixture of ground single crystals was charged in an evacuated quartz ampule 8 mm in diameter and 50 mm long. The ampule was heated for several hours to a temperature of 500°C, it was held for about 20 hours and then cooled with a temperature gradient of 40 degrees/cm at a rate of 10 degrees/hour. The product of the experiment was filamentary crystals of eutectic composition 2 to 3 microns in diameter. The lead chloride crystals are larger and more perfect than those obtained on the earth, the component distribution in them is quite homogeneous. The form of the ingots differed from ideal--deformation is visible, and one sample had a helical surface, which obviously was connected with the operation of the station gear when the eutectic was growing.



Samples of semiconductor glass hardened under space experimental conditions have greater homogeneity of chemical composition and have a wide pass band

Key:

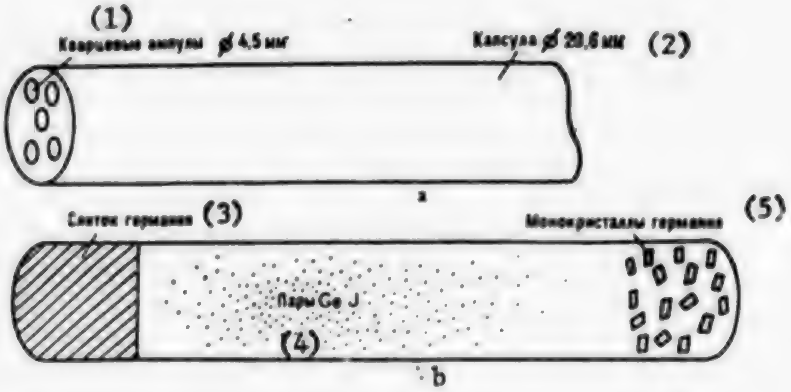
1. Logarithmic transmission coefficient, relative units
2. Transmission region, electron volts
3. On the earth
4. In space



Multicomponent semiconductors obtained on board the orbital station contain a monocrystalline part with more uniform distribution of components than their earth analogs

Key:

1. Cadmium content in the sample, %
2. Seed crystal
3. Sample length, cm
4. On the earth
5. In space



a- metal capsule by means of which the peculiarities of mass transfer in the gas phase were studied; b--five such quartz ampules were stacked inside the metal capsule

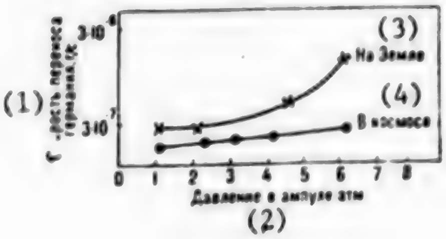
Key:

1. Quartz ampules 4.5 mm in diameter
2. Capsule 20.6 mm in diameter
3. Germanium ingot
4. Ge I vapor
5. Monocrystals of germanium

The experiment in the crystallization of univalent mercury bromide demonstrated the following: crystals grown on the earth and in space are also distinguished with respect to shape and size. Whereas the univalent mercury bromide crystals under earth conditions are grown in the form of platelets, on board the orbital station they acquire a fibrous shape which is more prospective for opticoelectrical instruments. The experiment with semiconducting glass was run on the "Kristall" device (germanium, sulfur, antimony). As a result, gas bubbles were formed on the surface of the space sample which decreased the contact of the glass with the surface of the ampule. For an hour the samples obtained (just as the analogs on the ground) were annealed at a temperature of 320°C and 400 to 425°C. The glass remelted on board the station turned out to be more homogeneous with respect to chemical composition, which increased the pass band of such glass and decreased the infrared absorption.

"SIRENA" (Polish People's Republic)

The Polish specialists set the following goal: to obtain ternary semiconductor compounds--cadmium-mercury-tellurium (from a melt on the "Splav" device), cadmium-mercury-selenium and lead-selenium-tellurium (from the gas phase on the "Kristall" device). These semiconductor compounds (infrared radiation sensors are made from them) are obtained also on the ground, but on the basis of a significant difference in specific weight, the components are separated, and the obtained materials have an inhomogeneous structure which has a sharply negative influence on their properties.



In space the mass transport is small and takes place as a result of diffusion. On the ground accelerated mass transport is observed in an analogous experiment as a result of convection.

Key:

1. Germanium transport rate, grams/second
2. Pressure in the ampule, atmospheres
3. On the ground
4. In space

In the experiment in which cadmium-mercury-tellurium compounds were obtained from the melt by the method of directional crystallization, growth took place from binary compounds. On the ground under such conditions polycrystals are always nucleated; under space conditions crystals having monocrystalline part were formed from the polycrystalline seed.

The content of one of the components (cadmium) in this part of the sample was close to the required magnitude, at the same time as in the earth analogs of the sample the value frequently is two times more. Homogeneous material made up about half the mass of the melt, and on the ground no more than 10 or 15 percent is obtained. In the experiment it is obvious that the homogeneous material can be obtained only with small crystal growth rates (for mass transport is determined by diffusion). At high growth rates undesirable gas bubbles appear in the crystals grown.

The quality of semiconductor crystals grown from the gas phase is influenced by the displacement rate of the crystallization front--at minimum drawing speeds of the ampule chemically homogeneous compositions without gas inclusions arise (the experiments were run on the "Kristall" device).

"BEROLINA" (German Democratic Republic)

An interesting varied program was prepared by the specialists of the German Democratic Republic in which studies were made of the influence of flight conditions on the processes of mass transport in the gas phase, crystallization of semiconductor compounds and the preparation of optical materials.

On the "Splav" device, an admixture semiconductor was obtained--bismuth antimonide--in an ordinary cylindrical ampule and in the gap between the two flat plates. After melting, when the temperature dropped, crystallization began with characteristic dendritic (tree) structure which then became a single crystal. The length of the section with dendritic structure in the space sample increased by 4 to 6 times by comparison with the ground analog. On the edges of the sample grown on the station, the distribution of the impurities becomes more uniform than on the ground.

Another semiconductor--lead telluride used in thermocouples and lasers--was obtained from the gas phase on the "Kristall" device. The lead telluride (melting point 924°C) was deposited on the substrate, the temperature of which in one experiment was 750°C, and in another experiment, 850°C. In the first case the material transport was small, and it was not possible to grow a normal crystal. In the second case the single crystal was grown. Blocks in the form of a mosaic were observed on its surface. No dislocations (disturbances of the crystal structure) were detected. It is unquestioned that with the approach of the substrate temperature to the melting point of the material, a single block must be formed. Experiments show the following: the mass transport rate under such conditions must be lower than on the ground.

The study of the peculiarities of mass transport in the gas phase performed on the "Splav" device was of significant interest. Five quartz ampules 4.5 mm in diameter each were stacked inside the metal capsule. On one end of the ampule (it was located in the hotter zone of the heating element of the "Splav" furnace at a temperature of 896°C) a piece of single germanium crystal was placed, crystallization of the germanium from the gas phase took place on the other end, the "cold" end of the ampule (its temperature was -620°C). The ampules differed from each other by the pressure of the gas medium (iodine) inside them. After the experiment it became clear that under conditions close to weightlessness, on board the station the transport rate of the material remains almost constant--$3 \cdot 10^{-7}$ gram/sec--and does not depend on the gas pressure in the ampule. Obviously, the mass transport in this case has a purely diffusion nature. In the experiments performed on the ground, the mass transport rate of the germanium essentially depends on the gas (iodine) pressure in the ampule. The scientists confirmed that the observed relations indicate that under ground conditions, convection is responsible for transport, the contribution of which increases with an increase in convection.

"PIRIN" (People's Republic of Bulgaria)

Bulgarian scientists studied the peculiarities of growing crystal faces, wetting under weightlessness and other physical processes.

The stability and structure of single zinc crystals grown under diffusion conditions from the gas phase in the presence of accompanying gases were investigated in one of the experiments on the "Kristall" device (at a maximum temperature of 380°C, 5 hours of holding and subsequent passive cooling). It was possible to discover that the improved faceting of the crystal is retained to the defined dimension. Then, on the face which grows from the periphery to the center, a depression is formed, and three-dimensional whiskers occur. The whiskers reinforce the material.

In one of the experiments on the "Splav" device an effort was made to obtain foam metal which is of significant interest for science and engineering (such experiments were started by Soviet specialists under the conditions of short-term weightlessness on the "Mir-2" high-altitude rockets). A quartz ampule with briquettes located in it which contained silumin, titanium hydride, silicon nitride and blowing agent were held at a temperature of 800°C for 10 minutes. A porous aluminum ingot was formed, and its structure is still to be studied.

Samples of materials obtained by the cosmonauts from Bulgaria, Vietnam, Cuba, Mongolia and Romania are at present being investigated. Therefore we shall basically limit ourselves to a brief description of the goals which were set during the experiments.

"ETVESH" and "BEALUTSA" (Hungarian People's Republic)

The "Etvesh" experiment was run on the "Kristall" device. It was necessary to investigate the influence of weightlessness on the process of obtaining semiconductor materials--gallium arsenide alloyed with chromium, indium antimonide and gallium antimonide. The name of the experiment is a type of play on words: first, it was the last name of a prominent Hungarian physicist Lorand Etvesh, and secondly, the word "etvesh" itself means "alloying" when translated.

The series of experiments under the title "Bealutsa" had as its goal the investigation of the morphology of an aluminum alloy with 4% copper during crystallization and the study of the admixture distribution and also the processes of diffusion, melting and crystallization under weightlessness conditions in the example of the aluminum-copper system.

"KHALONG," "IMITATOR" (Socialist Republic of Vietnam)

The "Khalong" cycle of experiments is part of a broad (jointly with Soviet specialists) research program connected with obtaining semiconductor materials on board the "Salyut-6" station by various production methods. The "Khalong-1" experiment is devoted to growing solid solutions of the bismuth-tellurium-selenium system, "Khalong-2" and "Khalong-3" are devoted to growing multicomponent crystals of the bismuth-antimony-tellurium system. These crystals serve as the base for thermoelectric elements based on the Peltier effect. The investigation of the growth rate of gallium phosphide crystals with different content of alloying admixtures under weightlessness conditions and calculation of the phosphorus diffusion coefficient in liquid gallium were the goals of experiments "Khalong-4" and "Khalong-5."

The developers of the "Kristall" gear were interested in the question of what the exact temperature inside the electric heating furnace installed on board the "Salyut-6" station is and where the heat transfer processes are not the same as on the ground. The "Imitator" experiment was set up for the solution of this important technical problem.

"SAKHAR" [SUGAR], "KARIBE" [CARIBE], "ZONA" [ZONE] (Cuba)

The "Sakhar" experiment was supposed to "tell" about the peculiarities of growing a single crystal of saccharose and help to grow organic single crystals from solutions under space flight conditions. The work was done on the "Kristallizator" gear developed and made in the Republic of Cuba. For 3 days the growth of these crystals was photographed by the "Praktika-EE-2" camera (German Democratic Republic).

The "Caribe" program included five technological experiments. (Caribe was a tribe of Indians which bravely fought for their freedom against the Spanish conquerors.) In the greater part of these experiments the goal was set of obtaining complex semiconductors of the type of germanium alloyed with indium and epitaxial layers of gallium arsenide. (Epitaxy is oriented growth of one single crystal on the surface of another.)

In the "Zona" experiment zone melting was carried out with a temperature gradient on single saccharose crystals.

"ALTAY," "ERDENET" (Mongolian People's Republic)

The purpose of the "Altay-1" experiment was investigation of the diffusion and mass transport in the melt of two metals solid and in the liquid state--lead and tin. A simultaneous study was made of the crystallization of melts forming the eutectic. In another experiment of this series an effort was made to grow an active semiconductor--crystalline vanadium pentoxide used to manufacture thermistors.

The investigation of the diffusion processes and redistribution of the admixtures during solution in water and crystallization of copper salts was performed in the "Erdenet" experiment.

"KAPILLYAR" (Romania)

Romanian specialists tried to obtain single crystals of given profile using capillary forces and investigate their influence on the distribution of admixtures in the melt. A study was made of the germanium distribution and the distribution of germanium with gallium additives in a molybdenum matrix. It must be noted that this experiment became a continuation of the experiment under the same name performed by Soviet scientists on the "Mir-2" high altitude rockets. Preliminary analysis of the samples obtained demonstrated the following: on the ground where the molten germanium flowed through a capillary (a molybdenum tube with inside diameter of about 2 mm) and then congealed, the obtained sample had the form of a "dumbbell," inasmuch as only part of the melt leaked through. In the space experiment the capillary forces of wetting instantaneously "pumped" the liquid germanium from one part of the ampule to the other--the space "pump" operated well.

Thus, materials were obtained which were better by comparison with the materials made on the ground or the initial samples, and important peculiarities of the behavior of multiphasal systems under conditions close to weightlessness were established. Some results turned out to be unexpected: the variation in the wetting characteristics, separation of a number of materials from the walls of the ampule while retaining contact at individual points. The possibility of more precise determination of the course of future experiments, improvement of the on-board equipment producing materials in near-earth orbit was discovered.

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SPACE BIOLOGY AND MEDICINE IN INTERCOSMOS PROGRAM

Moscow ZEMLYA I VSELENNAYA in Russian No 2, Mar-Apr 82 pp 32-35

[Article by USSR deputy minister of public health, corresponding member of the USSR Academy of Medical Sciences Ye. I. Vorob'yev and doctor of medical sciences A. R. Kotovskaya]

[Text] A station of the "Salyut" type permits complex studies to be made of near-earth space, processes occurring on the sun and distant objects of the universe, on our earth, in its atmosphere and the study of natural resources, and much more. Inasmuch as all of this is done with the active participation of man, newer and newer problems arise for space medicine which sometimes require very quick solution. It is natural that for this purpose it is expedient to combine the efforts, knowledge and capabilities of scientists from various branches of science and scientists from different countries.

This is why international cooperation of specialists in the field of space biology and medicine has continued for 14 years. The scientists of ten socialist countries (the People's Republic of Bulgaria, Hungarian People's Republic, Socialist Republic of Vietnam, German Democratic Republic, Mongolian People's Republic, Polish People's Republic, Cuba, Romania, USSR and Czechoslovakia) are performing joint studies under the "Intercosmos" program.

It has now become obvious that the primary limiting factor for the time man can spend in space is not the technical possibilities, but the capacity of the cosmonaut to "adapt" to weightlessness and to subsequent life on the earth. Therefore among the space flight factors, weightlessness is taking the central position.

In planning the first space flights, science could not answer accurately whether it is possible to live in weightlessness, whether the force of gravity is the necessary condition to normal vital activity. Weightlessness was considered to be an enormous danger to live beings, and some very gloomy forecasts were made. Flights by various biological subjects into space dispelled these fears. We now know that a live organism can adapt to an environment which is unusual and strange to it and can adapt to weightlessness.

In order to represent how the organism adjusts, what changes can occur in weightlessness, what the mechanism of the deviations and disorders that arise are, the Soviet Union has launched specialized biological satellites in the "Cosmos" series with various biological subjects on board.

Since 1973, five such satellites have been launched. Scientists and engineers of Bulgaria, Hungary, the German Democratic Republic, Poland, Romania, Czechoslovakia, the United States and France participated in the experiments.

It was possible to discover that prolonged weightlessness has no direct harmful influence on intracellular processes, including those connected with the division cycle and transmission of hereditary information. These data have theoretical significance, for they remove the basic biological restriction to further increase in the duration of manned space missions. At the same time it was discovered that weightlessness leads to obvious changes in a number of systems, for example, in the muscles and bones. Thus, signs of atrophy were observed in the bones, and there was a decrease in muscular mass and strength. These disturbances disappeared after some time. Fleshing out of the calcium was noted in the bony tissue. It is important to emphasize that in bony tissue, just as in muscle tissue, the greatest changes under the influence of weightlessness were noted in those parts of the skeleton which bear the greatest weight load under ordinary conditions of life on earth, that is, the bones of the extremities and vertebrae.

On the "Cosmos-936" satellite an interesting experiment was performed with artificial gravity where animals (rats) were rotated on special on-board centrifuges. It turned out that artificial gravity (approximately the same as on earth) prevented the development of structural and functional changes in the skeletal-motor apparatus and other functional systems of the organism. It was proved for the first time that artificial gravity actually promotes normal functioning of the human organism during prolonged space flights. Moreover, it is now considered as a universal means for protecting cosmonauts from destructive effects at prolonged weightlessness on future interplanetary flights.

The most difficult and morbid period is the first week under weightlessness conditions, a period of acute adaptation when changes and disturbances of the various systems of the organism capable, in turn, of having negative effects on the condition and fitness of the crew occur.

A comprehensive study of adaptation of the organism is required for the development of preventive measures, for effective medical support of manned space flights. These arguments were considered when setting up the scientific programs for international crews. In other words, many faceted medical studies on international flights of short (up to 7 days) duration were without a doubt justifiable.

During the course of nine international flights, the condition of the cardiovascular and respiratory systems, organs of sense, skeletal and motor apparatus, mental fitness and immunological resistance were analyzed.

Studies of the cardiovascular and respiratory systems made it possible to obtain information about the fact that defined loads (let us say, exercises on a veloergometer) cause more stress of the physiological systems in the organism than in analogous situations on the ground. The experiments were performed during flights of the cosmonauts from the Socialist Republic of

Vietnam, Cuba, Mongolian People's Republic, and Romania using on-board devices and instruments built in the Soviet Union and German Democratic Republic.

During the flight of the Soviet-Romanian crew, the method of ballistocardiography was used which made it possible to determine the contraction function of the heart and discover functional disturbances in the cardiovascular system. The Romanian instrument "Miokard" was used before the flight and after it to measure the duration of the cardiac cycle directly under physical load.

Redistribution of the blood in the organism from the lower part of the body to the chest cavity and head takes place under weightlessness. This, in turn, can lead to disturbance of normal "interrelations" between air and blood in the lungs. From this, the oxygen saturation of the blood is lowered, and consequently, the oxygen saturation of the tissues of the organism is lowered. A series of experiments were performed in which a study was made of the oxygen regime of the tissues (the skin of the hand) in flight. These experiments, under the main "Kislorod" [oxygen] were performed using a unique on-board instrument "Oksimetr" (Czechoslovakia) during flights by the cosmonauts from Czechoslovakia, Poland, the German Democratic Republic, and others. It was noted that the partial pressure of oxygen in the tissues was lowered, and its consumption was decreased.

Joint work of the specialists of the Soviet Union, German Democratic Republic, and Poland brought new information about the state of hearing and taste sensations of the cosmonauts. These studies were performed on the "Audio," "Shumomer" and "Elektrogustometr" developed in the German Democratic Republic and Polish People's Republic.

During the flight of the Cuban cosmonaut, ways to prevent changes in the muscular and supporting functions of the foot were evaluated by using an original device proposed by Cuban specialists--shaped arch supports put in the footwear which the Cuban cosmonaut wore in space.

The medical-biological research was prepared also by specialists from Vietnam, Mongolia and Cuba.

The medical support of manned space flights has demonstrated that in flight, especially during the first few days, disorders similar to seasickness are observed which cause dizziness, loss of appetite, nausea and sometimes vomiting in 30% of the cosmonauts. In the majority of cosmonauts illusions about the body position arise. These disorders naturally lead to reduced fitness, for the cosmonaut immediately strives for sharp limitation of his mobility (especially mobility of the head) which alleviates his condition. Accordingly, the development of measures of treating and preventing vestibular discomfort is acquiring enormous practical significance. An active search is now being made for effective pharmacological compounds. The pharmaceutical companies of Hungary and Poland have been brought into this work. The specialists of the well-known Hungarian company "Gedeon Richter" proposed the use of "Kavinton" which is being tested in the USSR. The laboratories of the Soviet Union, Bulgaria, the German Democratic Republic and Poland have greatly improved the methods of selecting the cosmonauts. The primary goal is to evaluate whether it is impossible to lower the medical requirements and restrictions on the condition of health and age of aspirers and candidates for future cosmonauts. Everyone understands that it is expedient to include highly qualified specialists of different profiles (astronomers, physicists, doctors, biologists and so on) in the crew of spacecraft along with the commander and flight engineer. However, unfortunately, such specialists, as a rule, have certain deviations in the state of health or are already older (40 or more years old). Therefore the evaluation of the stability of people of this category with respect to various functional loads, determination of reserve capabilities of their organism have great practical significance.

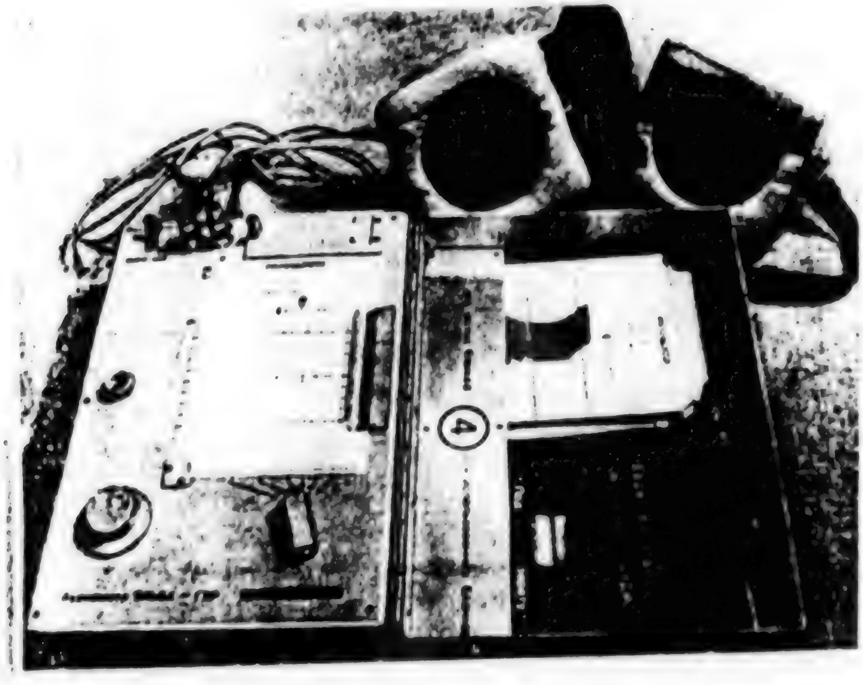
"Oksimetr" instrument by means of which the "Kislorod" experiment was run

Key:
1. electrodes
2. syringe

With an increase in the duration of space flights, the significance of the psychological reliability of the cosmonauts is increasing. The specialists are striving to determine the criteria of psychological adaptation of man to extraordinary conditions of his environment, to substantiate and recommend a number of measures which will improve the psychological state of man.

Soviet and Polish specialists have developed a special questionnaire which is used in flight by all members of the international expeditions. On this questionnaire questions are answered which pertain to the peculiarities of how the cosmonauts feel, estimates of how they are sleeping, posture, vision, hearing, smell, professional skills, psychological condition and aesthetic requirements. Each item is given a value on a scale of 5. The cosmonaut puts down the value most likely reflecting his condition (the "Opros" [interrogation] experiment). Analysis of the data obtained will permit determination of individual characteristics of psychological adaptation of each cosmonaut to flight. It turned out that the adaptive forces are different in the process of overcoming extraordinary living conditions in space. Those going into space for a second time, as a rule, adapted faster than those being sent up for the first time.

The mental fitness, memory, and attention span were evaluated using equipment developed in Bulgaria (the "Sredets" instrument) and Hungary ("Balaton" instrument).



"Audio" instrument

Hungarian "Balaton" instrument

The results of the performed studies indicate that no serious psychological problems arose interfering with the fulfillment of the assignment or leading to psychological disorders up to now. This stability was achieved by understanding the motivations for activity, the effectiveness of psychological selection, satisfactory living conditions on the spaceships, a balanced work and rest regime and also special measures with respect to psychological support of the crews.

Psychologists and specialists at the television centers of each country prepared interesting, pleasant video tape programs which included classical and light music, a musical show, folk dances and songs and views of familiar places. Looking at the video recordings during relaxation in space provided a normal, closer communication in flight and full-valued rest. This organization of leisure time is considered one of the components of psychological support of the crew in flight.

Thus, studies under the "Intercosmos" program during manned flights made it possible to determine the probability of development and the symptoms of disorders connected with the acute period of adaptation of man to weightlessness, estimation of the psychological characteristics of fitness of the cosmonaut during this period, estimation of certain methods and means of preventing unfavorable influences of weightlessness. The scientists obtained new materials for further expansion and deepening of the knowledge and concepts in the field of space biology and medicine.

The specialists of the socialist countries have succeeded in fulfilling the scientific programs of nine international crews. In past years the structure has been developed and experience in the preparation of joint international research acquired--from the ideas, the scientific programs, to implementation of them. Scientific and technical cooperation has been set up, and experience in the development and creation of special portable on-board gear and equipment, testing of it and delivery on board the spaceship has been acquired.

Twenty-eight different instruments and devices which were used in flight on the "Salyut-6" station and on biological satellites have been built within the framework of the international cooperation under the "Intercosmos" program.

There are grounds for hoping that the results obtained as a result of the efforts of the specialists of the Soviet Union and other foreign countries will be useful both for people in space and those on the earth.

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SPACE SCIENCES

UDC 581.521

STUDY OF ELECTRON FLOWS WITH E_e = 40-500 keV DURING QUIET PERIODS OF SOLAR ACTIVITY, USING CORRELATION AND SPECTRAL ANALYSIS METHODS

Moscow KOSMICHESKIYE ISSLEDOVANIYA in Russian Vol 20, No 5, Sep-Oct 82 (manuscript received 16 Sep 81) pp 700-704

ZEL'DOVICH, M. A. and TREBUKHOVSKAYA, G. A.

[Abstract] The authors examine the Galaxy and active processes in the Sun as possible sources of background flows of electrons with E_e = 40-500 keV in interplanetary space. Their experimental data were gathered from February 1973 to February 1974 by gas-discharge counters carried by the "Prognoz-3" artificial Earth satellite, and they limit themselves to the extramagnetospheric sections of its trajectory. Spectral analysis indicates that the background electrons are not particles accelerated during solar flares. Correlational analysis indicates that they are not of galactic or interplanetary origin and that if they are of solar origin, their source can be: 1) the entire surface of the Sun; 2) particles accelerated in solar flares; 3) particles accelerated in active areas outside flares. The authors favor the last hypothesis. Figures 3; references 6: 3 Russian, 3 Western.
[16-11746]

UDC 543.42:522.124

ELECTRONS WITH ENERGY LEVELS OF HUNDREDS OF MEGAELECTRONVOLTS IN NEAR SPACE

Moscow KOSMICHESKIYE ISSLEDOVANIYA in Russian Vol 20, No 5, Sep-Oct 82 (manuscript received 15 Jul 81) pp 705-713

GRIGOROV, N. L.

[Abstract] The author explains the operating principles of two types of instruments that were developed in order to register electrons with energy levels of about 10^2-10^3 MeV. He then lists the satellites that carried

them and the results of the measurements made with them and, after distinguishing between albedo electrons and those captured by the Earth's geomagnetic field, discusses both types in detail. He also discusses briefly the spectrum of electrons with energy levels of 10-100 MeV, then presents a number of conclusions based on his analysis of the experimental data. Figures 7; references 15.
[16-11746]

UDC 550.388

PARTICLE ACCELERATION DURING DEVELOPMENT OF DISCONTINUOUS INSTABILITY

Moscow KOSMICHESKIYE ISSLEDOVANIYA in Russian Vol 20, No 5, Sep-Oct 82 (manuscript received 14 Sep 81) pp 714-724

ZELENYY, L. M., LIPATOV, A. S. and TAKTAKISHVILI, A. L.

[Abstract] The authors carry out a sequential investigation of the process of particle acceleration during discontinuous instability, beginning with the linear phase and ending with saturation of the instrument. They solve the equations of motion for particles during both the linear and nonlinear phases and determine the rate of decline of particle density in the vicinity of a magnetic field's X-line, and discuss the energy spectrum of accelerated particles, with due consideration for the contribution made to it by incoming particles. Finally, they set up a numerical model of the particle acceleration process and find that it coincides qualitatively with their theoretical model of the acceleration dynamics. Figures 5; references 7: 1 Russian, 6 Western.
[16-11746]

UDC 523.042

DETERMINING PARAMETERS OF INTERSTELLAR WIND FROM OBSERVATIONS OF L_α-BACKGROUND AT GREAT DISTANCES FROM SUN

Moscow KOSMICHESKIYE ISSLEDOVANIYA in Russian Vol 20, No 5, Sep-Oct 82 (manuscript received 26 Mar 82) pp 725-729

BURGIN, M. S.

[Abstract] Although an optically thin (or fine) model can be used to approximate measurements of the interstellar wind's parameters at distances of no more than several astronomical units from the Sun, at greater distances the large effect of multiple scattering prevents the use of such a model. The author attempts to set up a model for the quantitative investigation of the effects of multiple scattering of solar photons in the interstellar

medium. He explains the approximations and assumptions he uses, along with his computation method, then discusses the results and their theoretical accuracy. Figures 2; references 15: 8 Russian, 7 Western.
[16-11746]

UDC 629.788

INVESTIGATION OF DESTRUCTION OF METEOR PARTICLES MOVING IN ATMOSPHERES OF EARTH, MARS AND VENUS

Moscow KOSMICHESKIYE ISSLEDOVANIYA in Russian Vol 20, No 5, Sep-Oct 82 (manuscript received 16 Nov 81) pp 730-735

APSHTEYN, E. Z., PILYUGIN, N. N. and VARTANYAN, N. V.

[Abstract] On the basis of a theoretical model developed in part by two of the authors, they analyze the motion and destruction of small stone meteors in the atmospheres of Earth, Mars and Venus and calculate their final mass and temperature, as well as the intensity of the luminescence and electron density of the trails they leave. Using equations from earlier works, they make calculations for particles 0.5 mm in diameter entering the Earth's atmosphere at angles of 30° and 90° and velocities of 30 and 60 km/s, then make some alterations in the parameters becuase of the differences between Earth's atmosphere and those of Mars and Venus and make the calculations for those planets. They also discuss how meteor particle observations can be of assistance in recovering the parameters of a planet's atmosphere. Figures 5; references 22: 20 Russian, 2 Western.
[16-11746]

UDC 551.521.8

DYNAMICS OF ENERGETIC ELECTRONS, BASED ON OBSERVATIONS MADE BY 'INTERCOSMOS-19' ARTIFICIAL EARTH SATELLITE IN APRIL 1979

Moscow KOSMICHESKIYE ISSLEDOVANIYA in Russian Vol 20, No 5, Sep-Oct 82 (manuscript received 24 Dec 82) pp 767-771

MINEYEV, Yu. V., SENCHURO, I. N., SPIR'KOVA, Ye. S., SHAVRIN, P. I., GLUKHOV, G. A. and KRATENKO, Yu. P.

[Abstract] After describing the satellite's orbital parameters and those of the Pero-ZI differential electron spectrometer that was used, the authors present the results of measurements of electron flows made in the Earth's inner and outer radiation belts before, during, immediately after and several days after a severe magnetic storm. By comparing measurements made on orbits with no more than 1° longitudinal separation, they discover

some temporal variations in the differential electron flow densities that are apparently related to the magnetic storm. Figures 2; references 6: 3 Russian, 3 Western.
[16-11746]

UDC 519.4

EFFECT OF PHOTOEMISSION ON DISTURBED ZONE NEAR SATELLITE

Moscow KOSMICHESKIYE ISSLEDOVANIYA in Russian Vol 20, No 5, Sep-Oct 82 (manuscript received 21 Dec 81) pp 771-773

GORBUNOV, S. A. and MOSKALENKO, A. M.

[Abstract] The authors discuss the effect of photoemissions from the surface of a satellite illuminated by the Sun on the electrical field and concentration of particles in the disturbed zone around the satellite. They find a solution for a satellite illuminated from the front, but do not attempt to solve the problem for one illuminated from behind, as it is considerably more complicated. Figures 2; references 4: 2 Russian, 2 Western.
[16-11746]

UDC 550.383

PENETRATION OF SOLAR WIND'S MAGNETIC FIELD INTO COMETARY IONOSPHERES

Moscow KOSMICHESKIYE ISSLEDOVANIYA in Russian Vol 20, No 5, Sep-Oct 82 (manuscript received 22 Oct 81) pp 779-783

MAROCHNIK, L. S.

[Abstract] The author attempts to show that the solar wind's magnetic field does penetrate cometary ionospheres, in contrast to the situation arising when the solar wind interacts with the ionosphere of a nonmagnetic planet. He limits himself to a single effect resulting in this penetration: "charging" of the solar wind's plasma by ionizing comet molecules. Dismissing the case where the mass velocity of the medium coincides with the speed of the magnetic field, where the solar wind's magnetic field does not penetrate the plasma of a cometary ionosphere but which is not a case for practical consideration since it does not occur, he uses a model consisting of the ionized component of the solar wind and cometary ionosphere plasmas to show that the indeterminacy of the available information on the power of the source of neutrals in a comet's nucleus and the ionization rate makes it possible to say only that the solar wind's magnetic field does pass through the magnetic field-cometary ionosphere interface at a speed ranging from several to hundreds of kilometers per second. References 4: 2 Russian, 2 Western.
[16-11746]

INTERPLANETARY SCIENCES

'VENERA-13' MASS SPECTROMETER STUDIES OF ATMOSPHERIC GASES ON VENUS

Moscow ZEMLYA I VSELENNAYA in Russian No 5, Sep-Oct 82 pp 19-25

[Article by V. G. Istomin, doctor of physicomathematical sciences: "Rare Gases on Venus"]

> [Text] Early in the morning of 1 March 1982, the descent vehicle of the Venera-13 station entered the dense layers of the planet's atmosphere. At an altitude of about 23 km above the surface of Venus, a mass spectrometer was turned on. Engineer K. V. Grechnev quickly identified in the mass spectra being received peaks of isotopes of neon-20 and neon-22. "I see neon isotopes," he said over the telephone from the Crimea. This information, received within less than 15 minutes after the instrument was turned on there, on board, meant that we had managed to measure the isotopic composition of neon (one of the "rare" gases) present in negligible amounts in the atmosphere of the planet that is our closest neighbor.

Historical Information

Earth's atmosphere contains "rare gases," in other words, inert, or "noble": helium, neon, argon, krypton and xenon are present in extremely small concentrations. The most abundant of them in the earth's atmosphere is argon (about one percent). The amount of neon is about 18 millionths, helium, about 5, krypton, about 1, and xenon, less than a ten millionth (by volume). The history of the discovery of rare gases in the earth's atmosphere now goes back over 200 years. Neon was isolated from air less than 90 years ago (W. Ramsay and M. Travers, 1898); the first indication of the existence of the two isotopes of neon was obtained in 1912 by J. J. Thomson, and conclusively confirmed in 1920 by measurements with the first mass spectrograph by F. Aston. By the fifties, measurements had been made of the isotopic composition of essentially all elements, including naturally the inert gases; by the sixties, it became evident that the universe, solar system and even earth are essentially isotopically nonhomogeneous. The first non-earth objects studied with mass spectrometers in earth laboratories were the meteorites and the rare gases contained in them; the isotopic composition of tnese gases were found to be very different from that of the rare gases in the earth's atmospnere. Gradually, it became evident that threads from the study of isotopy of the elements in the various space objects extend to solving the problem of the origin and evolution of the earth and the other planets in the solar system.

Naturally, as technical capabilities emerged, the atmospheres of the closest planets also began to be included within the scope of objects of investigation of the chemical and isotopiccomposition.

The task of finding rare gases in the Venusian atmosphere turned out, it seems, to be more difficult than on Earth, although it was done within a shorter time. The first studies of the composition of the Venusian atmosphere with the space vehicles (Venera-4 -- Venera-8) were done by using simple instruments: gas analyzers. These instruments could only inform us of the presence of ingredients, the concentration of which was units or several tenths of a percent. But even these rough estimates, obtained with the various space vehicles, differed strongly from each other, and the reasons for these differences were not always clear.

Arguments for Mass Spectrometers

The situation was radically changed with the new-generation stations, starting with Venera-12, where highly precise analytic instruments (including the mass spectrometer and gas chromatograph) were installed.

The mass spectrometer began to be used in space exploration about 25 years ago as early as the third satellite. The first such instruments yielded valuable information on the composition of inert and ionized gas in earth's upper atmosphere and helped reveal the features of its structure and dynamics. All existing models of earth's upper atmosphere and ionosphere are based to a considerable extent on data from mass spectrometry from rockets and satellites.

A major property of the mass spectrometer, well proven in research of the upper atmosphere, is its complete lack of "prejudice" with respect to the object of investigation. The instrument is not programmed in advance to detect any specific chemical elements or compounds of them, but records everything that falls within the range of the mass numbers of the mass spectrometer. Thanks to this, at the outset of investigating earth's atmosphere by rockets, for example, it was found that the lower part of the ionosphere owes its existence not at all to nitrogen and oxygen, but to a compound of them: ions of nitric oxide. Also, ions of metals were found quite unexpectedly in earth's atmosphere: magnesium, calcium, iron, titanium as well as other elements (silicon, for example) that one would think are "illegally" present in earth's nitric oxide atmosphere. This property of the mass spectrometer determined its selection as one of the basic analytic instruments in the research complex for the new-generation Venera stations.

A second, and hardly less important circumstance, is the capability of obtaining from the mass spectrometer information not only on the chemical, but also on the isotopic composition of matter under investigation. As is well known, all elements in Mendeleyev's periodic system exist in the form of a mixture of two (or more) stable isotopes. Recall that isotopes are a variety of the same chemical element that differ only by atomic mass, but have an identical number of protons in the composition of the nucleus and the same position in Mendeleyev's table. It is well known, for example, that in addition to the most widespread isotope with mass number 16, oxygen has isotopes with mass numbers 17 and 18; atmospheric nitrogen is a mixture of isotopes, the atomic mass of which is 14 (the "basic" isotope) and 15. The most abundant inert gas on earth, argon, has three isotopes: the "basic" one is argon-40, while argon-38 and argon-36 are rarer on earth.

The third "trump card" of the mass spectrometer is the capability of measuring concentrations of components in a wide range. Finally, the last (by counting, but not in importance) argument for selecting the mass spectrometer is the wealth of experience gained in the Soviet Union in the development and design of these instruments and in making mass spectrometric studies of the composition of earth's upper atmosphere with rockets and satellites.

But the problem posed by our nearest neighbor, Venus, it seemed, surpassed in complexity everything with which mass spectrometry in general and space mass spectrometry in particular had been concerned. Up to a 100 atmospheres of pressure at up to 500°C! After all, the mass spectrometer is a vacuum instrument. For normal operation of the mass analyzer, the pressure of the gas in it must be very low, no more than 10^{-5} torrs, in other words, a billion-fold lower than that at the Venusian surface....

This was one of the difficulties in using the mass spectrometer to analyze dense atmospheres. All "earth" (laboratory) mass spectrometers operate with vacuum pumps that first create the forevacuum to 10^{-1}- 10^{-2} torrs, and then a high-vacuum pump provides the working conditions needed.

Also needed was a method (and the invention of a device to implement the method) which would provide for inserting in the instrument a precisely dosed portion of gas with a volume in the hundredths of a cubic millimeter (at "normal" temperature and pressure). A solution was found at the edge of the capabilities of modern vacuum technology and engineering: A vacuum system was developed for a mass spectrometer that has extremely small internal gas separation and negligible leakage of gas from outside. Thanks to this, the vacuum in the instrument can be maintained for an indefinitely long time by the same sole high-vacuum (getter ion magnetodischarge) pump. Moreover, in the non-working state, the pump is naturally turned off so that pumping out is effected only through sorption (absorption) of chemically active gases by sprayed titanium. The mass spectrometer analyzer is connected to the external environment by a valve capable of inserting into the instrument within thousandths of a second the required amount of gas, and no more and no less.

MX-6411 Mass Spectrometer

This instrument, used on the Venera 11-14 stations was developed in the SKB [Special Design Bureau] for Analytic Instrument Making of the USSR Academy of Sciences together with the Institute of Space Research of the USSR Academy of Sciences and the Sumskiy Plant for Electronic Microscopes imeni the 50th Anniversary of the All-Union Lenin Komsomol.

The dynamic radio-frequency mass analyzer (which the MX-6411 is) resembles a tube in design. The analyzer contains 20 plane-parallel grids, and an ion source and a collector at opposite ends of the grid package. The gas enters the "source of ions" where the atoms and molecules are ionized by "electronic shock." The ions then enter the mass analyzer proper where they, accelerated initially by the constant electric field, receive addition energy in the tri-section radio-frequency stages. Since the time during which an ion flies through a radio-frequency stage is commensurate with the potential change period, ions with the mass number M_0 are accelerated (with a fixed value of frequency and accelerating potential) while ions with any other mass numbers are retarded. Passing the accelerated ions through the subsequent stages produces acceleration of them here too. Having placed brake grids in the path of the ions and selected the "braking potential," one can isolate in the collector only the maximally accelerated ions with mass number M_0, i.e. select by masses.

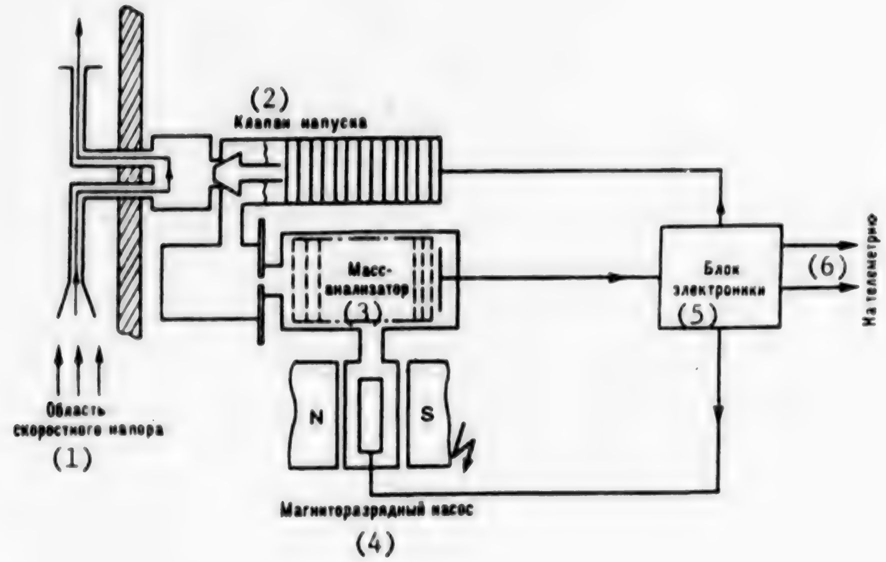

Fig. 1. MX-6411 mass spectrometer

Key:

1. velocity head area
2. input valve
3. mass analyzer
4. magnetodischarge pump
5. electronic unit
6. to telemetry

In the MX-6411 instrument, varying the frequency from 7.5 to 2.2 MHz allows covering a range of mass numbers from 12 to 140 atomic mass units (a.e.m.).

The MX-6411 mass spectrometer consists of the analytic system (combining the radiofrequency analyzer, ion source and the getter ion magnetodischarge pump), the electrometer attached to the analyzer base, the input valve connected to the analytic system by a flexible thin pipe, and the electronic unit. Since the mass spectrometer was installed inside one of the hermetically sealed compartments in the descent vehicle, a system of two pipes was included in it. During the descent of the vehicle in the Venusian atmosphere, the pipes were used to provide for constant blowing of atmospheric gas through the input valve. The input funnel was put on the vehicle in the "head" area (area of increased pressure due to vehicle motion, and the outlet end of the pipes was put in the area of reduced pressure. The instrument electronics, receiving commands from systems on board the station, controls its operation according to a specific cyclogram. On a signal from the onboard control system, the instrument is switched to the "search" mode. In this mode, every two seconds the input valve receives an electric control pulse, the amplitude of which increases successively. The instrument rapidly records the mass spectra, covering the entire range within a second. The getter ion pump is turned

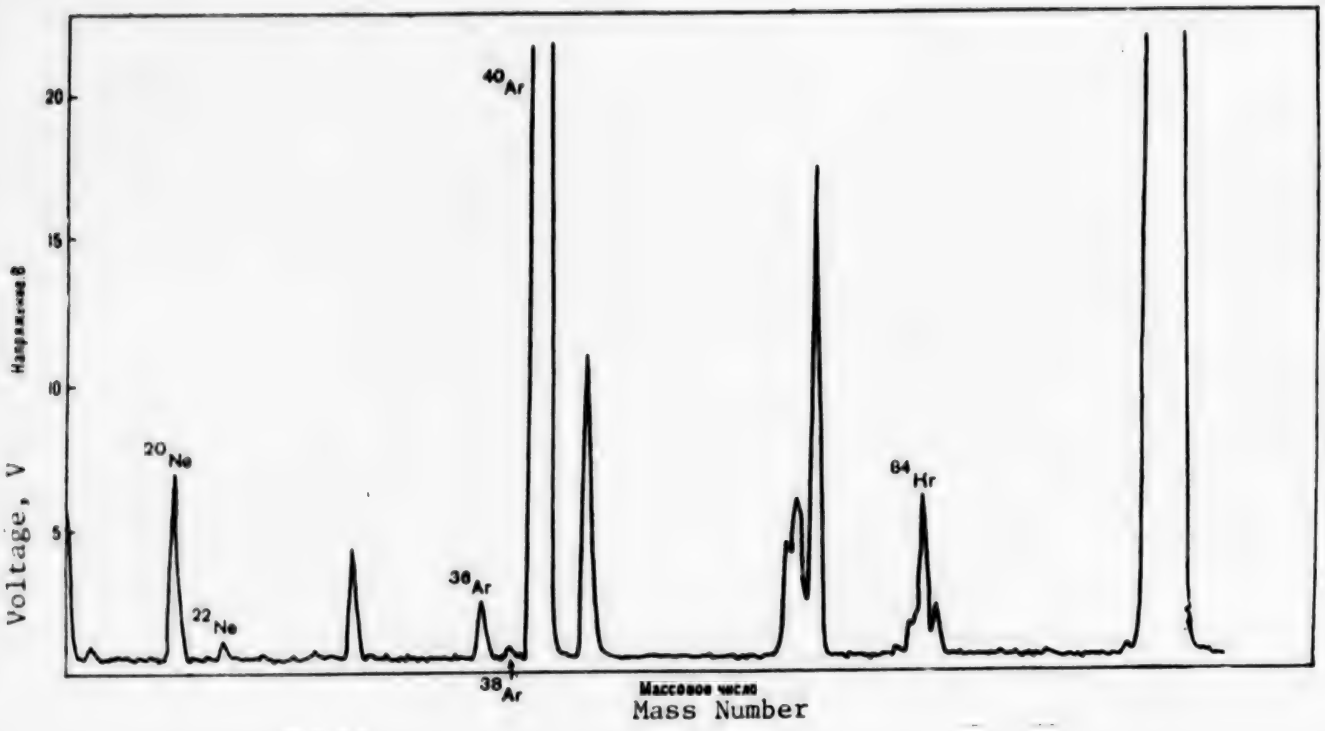

Fig. 2. Mass spectrum of calibration mixture; carbon dioxide and small additions of inert gases, neon, argon and krypton at the level of expected abundance of them in the Venusian atmosphere. Instrument sensitivity is demonstrated by the argon-38 peak: its content is about 120 billionths by volume. Resolution is demonstrated by the peaks of neon and argon. This spectrum was obtained in the process of a ground try out of the Venera-13 station.

on and in the intervals between the input valve pulses pumps out the gas entering the instrument. With each successive cycle, the amount of gas going into the instrument is approximately doubled (in all, there are 64 levels of "search" and 64 gradations of the input value, respectively). When one of the portions leads to the point where some peak of the mass spectrum exceeds the preset level of the discriminator, the instrument is switched to the "mode for analysis of chemically active components." Scanning the mass spectra takes 7 seconds. To increase sensitivity before the second mass spectrum, a gas portion twice exceeding that which led to tripping of the discriminator is inserted into the instrument. Since the magnetodischarge pump in the instrument remains on, pumping occurs at the same time as recording of spectra.

Upon completion of a cycle of "chemical analysis," the instrument is again switched to the search mode (with repetition of portions of the same value), and when the discriminator is tripped again, the magnetodischarge pump is turned off. The instrument records two 7-second measuring spectra of the mixture, now considerably enriched with inert components since pumping them out was stopped, and the sprayed titanium of the magnetodischarge pump sorbs only the chemically active CO_2 and N_2 making up the Venusian atmosphere. Further, over a period of 32 seconds, 16 of the same portions of the gas are inserted into the instrument, and the

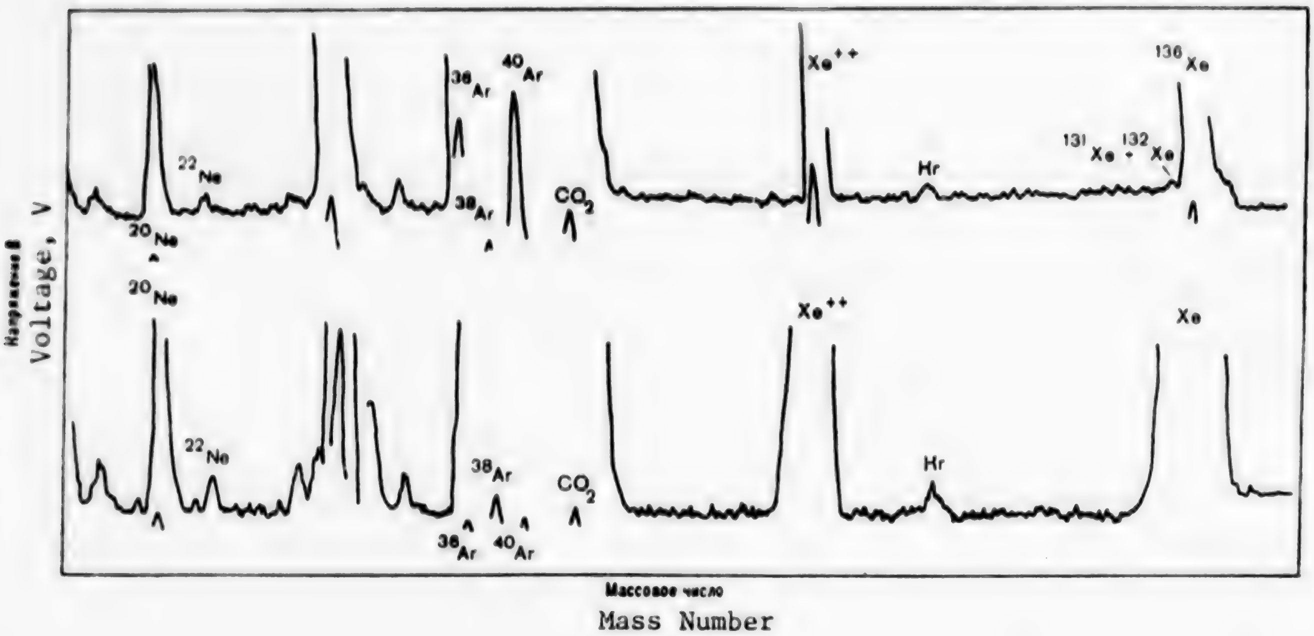

Fig. 3. Primary (unprocessed) mass spectra obtained with the Venera-13 (bottom) and Venera-14 (top) stations in the modes of noble gas analysis. The mass peaks of neon-22, krypton and xenon (131-132) are recorded on the first scale: the highly sensitive output of the instrument; the mass peaks of neon-22 are recorded on the second scale; the mass peaks of argon, isotopes with atomic weight of 36, 38 and 40, are recorded on the second and third scales of the instrument. A comparison with the preceding figure shows an "anomaly" of the isotopic composition of argon: in the mass spectra of the Venusian atmosphere, the peaks of argon-36 and argon-40 are about equal.

7-second measuring spectra (up to 16-18 spectra) are recorded again. At this time, absorption of CO_2 and N_2 is continuously going on and consequently even more enrichment of the mixture with inert gases. This is how the highest sensitivity to noble gases and their isotopes is achieved. The sequence of measuring spectra is broken by the next signal received from the station, after which the entire cyclogram resumes.

Despite the fact that the MX-6411 is more sensitive than many of its earth "counterparts" (it detects about 10^{-8} volume fraction of an inert gas isotope), the instrument weighs only 9.5 kg and uses about 17 W.

Characteristics of mass spectrometers are confirmed by a mass spectrum of a calibrating mixture obtained in the mode of analyzing inert gases during ground trials of the Venera-13 station and computer processed to avoid recording gaps when the instrument scales are switched. Sensitivity is demonstrated by the value of the mass peak of argon-38, the content of which was about 1.2×10^{-7} (120 billionths by volume) in the mixture. From this spectrum of the calibration mixture, in particular, it can be seen that argon of "normal" (typical for atmospheric argon) isotopic composition is present in it: the argon-40/argon-36 ratio is about 300. The procedure for obtaining and processing the calibration mass spectra in precision followed that adopted for flight mass spectra. This was done to improve the metrological characteristics of the entire complex of "instrument - data transmission system - processing system" which is especially important for obtaining undistorted data on the isotopic make up of noble gases.

Shown in fig. 3 are examples of the recording of unprocessed telemetric records of mass spectra obtained in the mode of analysis of inert gases on the Venera 13 (bottom) and 14 (top) stations. Well evident in the spectra are the peaks of the isotopes of neon-20 (top of the peaks is on the second scale) and neon-22 (on the first scale). Peaks of the isotopes of argon-36, argon-38 and argon-40 are recorded on the second and third scales. Well evident is the "anomaly" of the isotopic composition of argon in the Venusian atmospnere: The peaks of argon-36 and argon-40 are about equal. Also evident are the peaks of the unresolved group of isotopes of krypton (the maximum is krypton-84). Finally, in the top spectrum (Venera-14), next to the large peak of xenon-136 inserted into the instrument for technological purposes, one can see the composite peak of xenon-131 and xenon-132, isotopes that are part of the Venusian atmosphere. In all, about 250 mass spectra were obtained on the Venera-13 and 14 vehicles.

Rare Gases in the Atmosphere of Other Planets

In December 1978, 3.5 years ago, Venus was investigated by seven gas analytic instruments: Two gas chromatographs amd five (!) mas spectrometers studied the chemical and isotopic composition of its atmosphere. Of these, three mass spectrometers were installed on the Pioneer-Venus American vehicles and two on the Venera-11 and Venera-12. In March 1982, there were another two mass spectrometers and two gas chromatographs added to these instruments on the Venera-13 and Venera-14.

Mass spectrometric experiments in the United States on the Pioneer-Venus involved such well known specialists as A. Nir (he was the one who made the most precise measurements of inert gases in earth's atmosphere back in the fifties), Nir's student, G. Hoffman, G. Taylor and W. von Zan (FRG). The apparatus developed by U.S. scientists was perhaps somewhat complicated and, in our opinion, not always justified. For example, Hoffman's mass spectrometer had five vacuum pumps while ours had only one. The resolution by masses of one of the American mass spectrometers considerably exceeded that of the MX-6411, but the system for sample input on the Soviet instrument was more successful. The American instrument, which analyzed the lower Venusian atmosphere, after passing through the cloud layer was "blocked" for a lengthy period: a droplet of sulfuric acid closed the inlet by the point of the tubule-leak and seriously damaged normal operation of the mass spectrometer, having also hindered analysis of data. From a comparison of results, it was found that domestic instruments nad a lower level of internal background. As a result, actual sensitivity was close to design, while systematic errors of measurements related to internal backgrounds were absent in the majority of the mass spectrum lines.

Here is an example: For technological purposes, U.S. scientists used isotopically enriched xenon-136 with a content of the basic isotope of only about 95 percent, while the State Stock of Stable Isotopes prepared for us xenon-136 with a purity of 99.99 percent. This was chiefly reflected in the level of preflight preparation of the mass spectrometer.

Now about the main thing. The sensational conclusion that could be drawn literally from the first glance at the the mass spectra consisted in the surprisingly large content (abundance) of argon-36 and argon-38 on Venus compared to Earth. This fundamental discovery was made essentially at the same time on the Pioneer Venus and Venera-11 and Venera-12 spacecraft in December 1978. It has to be noted that from the American measurements, the content of argon-40 on Venus was not cited at all in the early publications, and later, it was given with a large error because of the large internal background of the instrument at the argon-40 line.

The importance of this discovery becomes evident when it is recalled that almost all the argon in earth's atmosphere consists of the argon-40 isotope which came about as a result of the decay of radioactive potassium-40 from the earth's core. But on Venus, radiogenic argon-40 and non-radiogenic argon-36 and argon-38 are present in equal amounts. Thus, it was found that the relative concentration of non-radiogenic ("primary") isotopes of argon and the absolute abundance of them exceeded that in Earth's atmosphere 300- and 100-fold, respectively. These facts irrefutably attested to the essential difference in the conditions of formation of the atmospheres of these planets.

Other results from mass spectrometric measurements on the Veneras and the Pioneer Venus of rare (and not just the rare) gases differed strongly from the beginning. The difference was especially noticeable in the early publications of the results by U.S. scientists. For some major components (nitrogen and argon-40), evaluations were not made at all, and in later articles, the difference with our measurements became less important. But all the remaining differences and relatively large values of errors have put on the agenda the issue of collation of the Soviet and the American instruments. During meetings in Moscow in April 1979 and January 1980, the program for calibrations of all the mass spectrometers and gas chromatographs was drawn up. This program was carried out rather slowly, but substantial progress was made soon after the venera-13 and Venera-14 flights. The first check calibration mixtures containing argon-36 and argon-40 in equal amounts were sent to the Institute of Space Research of the USSR Academy of Sciences.

Why is the study of rare gases and their isotopic composition in atmospheres of other planets so interesting and important? Primarily because this research is absolutely relevant to evolving and expanding our concepts of the universe. For example, the discovery of the "anomalous" isotopic composition of argon on Venus at once allowed drawing a number of very serious conclusions. Since the noble gases do not enter into any chemical transformations and are preserved on a planet throughout the entire time of its existence, they are used as a reliable "witness to the origin" of the planet's atmosphere. Therefore, M. N. Izakov of the Institute of Space Research, USSR Academy of Sciences, in analyzing the early results of the mass spectrometric measurements of rare gases on Venus, suggested that the greater part of primary isotopes of the noble gases ended up in the atmospheres of the planets in the earth group (Venus, Earth and Mars) thanks to the accretion of gas from the protoplanet cloud directly on the growing planets in the early stages of their formation. This hypothesis, just as other hypotheses on the origin of atmospheres, is continually subjected to verification and refinement as new experimental data arrives relative to the abundance of rare gases on Venus and on their isotopic composition.

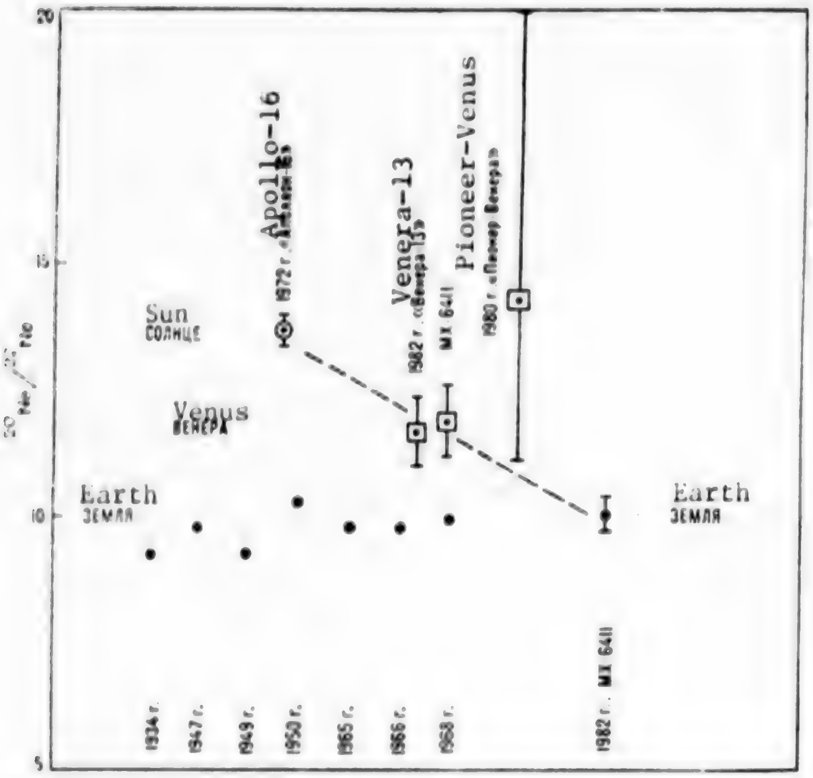

Fig. 4. Results of measurements of isotopic composition of neon (neon-20/neon-22 ratio) for the atmospheres of Earth and Venus and for the solar wind. Error flags are shown. Measurements on Venera-13 were supported by the measurements of the isotopic ratio of earth's neon made by the same mass spectrometer in prelaunch trials of the spacecraft. These (earth) data match well the data obtained by other authors (1934-1968).

One of the latest results which was also difficult to predict is the precise values of the isotopic composition of neon obtained in measurements on the Venera 13 and 14 spacecraft. The high sensitivity of the instruments allows meauring neon-20 and neon-22 almost in each spectrum. The neon-20 concentration is about 10 millionths which matches well the data from measurements with a gas chromatograph on the Pioneer Venus and with previous results obtained with mass spectrometers.

But what is the istopic composition of Venusian neon? Venera-13 data indicate that it differs considerably from earth's and the solar. What follows from the figures given below?

Body	$^{20}Ne/^{22}Ne$
Sun	13.7 ± 0.3
Venus	11.8 ± 0.7
Earth	10 ± 0.3
Mars	?

It has not been ruled out that these data indicate a process of differentiation of isotopes in the protoplanet cloud. Unfortunately, there is clearly insufficient data on Mars: Measurements on the (U.S.) Vikings did not yield data on neon isotopes. Perhaps further processing of results from experiments on the last Veneras will allow discovering the effects of the same indication in other rare gases? Analysis of the results continues....

PHOTO CAPTIONS

a.	p. 20	Laboratory mockup of radiofrequency mass analyzer. Developed at the Institute of Applied Geophysics, USSR Academy of Sciences (1956).
b.	p. 20	RMS-1 mass spectrometer used on the third satellite and high-altitude geophysical rockets (1957-1960).
c.	p. 20	MX-6405 radiofrequency mass spectrometer used on the Elektron series satellites (1964-1965). Developed at the Special design Bureau for Analytic Instrument Making, USSR Academy of Sciences.
d.	p. 20	MX-7407II radiofrequency mass spectrometer used mainly on the MR-12 meteorological rockets (1965-1980). Developed at the Special Design Bureau for Analytic Instrument Making, USSR Academy of Sciences, and produced in series by the Sumskiy Plant for Electronic Microscopes imeni the 50th Anniversary of the All-Union Lenin Komsomol.
e.	p. 21	Overall view of the MX-6411 mass spectrometer installed on the Venera 11, 12, 13 and 14 spacecraft.

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CSO: 1866/42

UDC 523.042:523.42

INVESTIGATION OF AEROSOL IN VENUS' CLOUD LAYER BY 'VENERA-12' AUTOMATIC INTERPLANETARY STATION (PRELIMINARY DATA)

Moscow KOSMICHESKIYE ISSLEDOVANIYA in Russian Vol 20, No 3, May-Jun 82 (manuscript received 24 Dec 79) pp 435-441

SURKOV, Yu. A., KIRNOZOV, F. F., GUR'YANOV, V. I., GLAZOV, V. N., DUNCHENKO, A. G., KUROCHKIN, S. S., RASPUTNYY, V. N., KHARITONOVA, E. G., TATSIY, L. P. and GIMADOV, V. L.

[Abstract] The "Venera-12" automatic interplanetary station's descent vehicle carried an instrument that gathered aerosol from Venus' cloud layer and subjected it to X-ray radiometric analysis for the purpose of determining its element composition. The instrument was calibrated for sulfur, chlorine, mercury and argon, with due consideration for both the increasing density of the atmosphere and the increasing accumulation of aerosol collected on the instrument's filter during the descent. Using the data obtained by this instrument and in three other experiments, the authors conclude that there appears to be a 2-km thick layer of aerosol, with its highest concentration at altitudes of 47-51 km. Its basic components appear to be compounds containing chlorine and possibly sulfur, although in a postscript concerning an analogous experiment performed with the "Venera-14," the data appear to suggest that sulfur is the basic component. Figures 7; references 8: 3 Russian, 5 Western.
[113-11746]

UDC 523.042:523.42

SPECIAL FEATURES OF TECHNIQUE FOR ANALYZING AEROSOL IN VENUS' CLOUDS

Moscow KOSMICHESKIYE ISSLEDOVANIYA in Russian Vol 20, No 3, May-Jun 82
(manuscript received 25 Nov 81) pp 442-448

PETRYANOV, I. V., ANDREYCHIKOV, B. M., KORCHUGANOV, B. N., OVSYANKIN, Ye. I., OGORODNIKOV, B. I., SKITOVICH, V. I. and KHRISTIANOV, V. K.

[Abstract] The experiment conducted to determine the composition of the aerosol in Venus' clouds, using an instrument on board the "Venera-12" automatic interplanetary station's descent vehicle, was based on the fact that when affected by X-ray or corpuscular radiation with a certain energy level, an atom of a chemical element being investigated is excited and, upon returning to its original state, emits an X-ray quantum with an energy level that is characteristic of an atom of the irradiated element. The instrument consisted of a fiber filter with special requirements and the analytical cell of the X-ray radiometric sensor, both of which are described in detail. The authors also describe the calibration process that was used. After analyzing the data that were obtained, they conclude that the basic mass of the aerosol in the cloud layer at altitudes of 49-58 km consists of elements with $Z < 13$. Figures 6; references 22: 11 Russian, 11 Western.
[113-11746]

UDC 523.42

RESULTS OF RADAR OBSERVATIONS OF VENUS ON WAVELENGTH OF 39 CENTIMETERS IN 1980

Moscow ASTRONOMICHESKIY ZHURNAL in Russian Vol 59, No 4, Jul-Aug 82
(manuscript received 7 Jan 82) pp 625-630

KOTEL'NIKOV, V. A., ALEKSANDROV, Yu. N., ANDREYEV, R. A., VYSHLOV, A. S., DUBROVIN, V. M., GRISHMANOVSKIY, V. A., ZAYTSEV, A. L., KAYEVITSER, V. I., KRYMOV, A. A., PETROV, G. M., RZHIGA, O. N., KHASYANOV, A. F. and SHAKHOVSKIY, A. M., Institute of Radio Engineering and Electronics, USSR Academy of Scientists

[Abstract] Using improved equipment, researchers at the USSR Academy of Sciences' Institute of Radio Engineering and Electronics, in collaboration with a number of other organizations, made radar observations of Venus at distances of 161 million to 94 million km from Earth from 15 Feb to 15 Apr 80. They measured Venus's distance and speed. The distance measurements were accurate to within 6 km, whereas the accuracy of the speed measurements was 3 cm/s. The observations were also used to construct a profile of Venus's surface relief along a track from 1°0' S. Lat, 70° Long.

to 3°7' S. Lat, 230° Long., wherein two mountainous areas were found. Figures 4; references 10: 9 Russian, 1 Western.
[30-11746]

UDC 535.24:523.42

VENUSIAN ATMOSPHERE ACCORDING TO DATA FROM OPTICAL MEASUREMENTS ABOARD 'VENERA-11' AND 'VENERA-12' SPACE VEHICLES

Moscow KOSMICHESKIYE ISSLEDOVANIYA in Russian Vol 20, No 4, Jul-Aug 82 (manuscript received 4 Nov 81) pp 572-594

GOLOVIN, Yu. M., MOROZ, V. I., MOSHKIN, B. Ye., SAN'KO, N. F. and EKONOMOV, A. P.

[Abstract] Measurements of the spectrum of solar radiation were made in the deep layers of the Venusian atmosphere with a resolution which made it possible to discriminate the absorption bands of atmospheric gases. The interpretation of these measurements gives new information important for several different aspects of physics of the Venusian atmosphere. The purpose of this review is to outline the results of past measurements and set forth fundamental conclusions in accordance with the present-day status of the problem. The following are among the conclusions drawn on the basis of the presented data. The total flux of solar radiation at the surface at the site of the "Venera-11" landing was 78 $W\cdot m^{-2}$. The mean flux value at the subsolar point, according to averaged data for three Soviet and one American probe, was 90 ± 12 $W\cdot m^{-2}$. The mean heat flux per unit surface is 17.5 ± 2.3 $W\cdot m^{-2}$. The part of the radiation heat flux falling in the range 0.45·1.55 μm is ~15 $W\cdot m^{-2}$ above 48 km and ~45 $W\cdot m^{-2}$ below 48 km. The lower boundary of the Venusian cloud layer is at about 48 km at the landing sites of both stations. The investigated part of the cloud layer (63-48 km) at the landing sites of both stations has an approximately identical structure, consisting of three parts, the boundaries being situated at altitudes of approximately 51 and 57 km. The lower layer is the densest. The optical thickness of the cloud layer in the range 0.5-1.0 μm is not dependent on wavelength. The optical thickness of the cloud layer below 63 km was 29 and 38 units at the landing sites of the "Venera-11" and "Venera-12" respectively. The albedo of single scattering in the cloud layer outside the absorption bands is very close to 1. Below 48 km there is an aerosol scattering medium whose optical thickness is highly dependent on wavelength. The average size of particles in the medium below the clouds is about 0.1 μm. In the spectra it is easy to identify CO_2 and H_2O bands whose intensity increases as the probes descend. The mean value of the H_2O mixing ratio in the atmosphere beneath the clouds is $3\cdot10^{-5} < F_{H_2O} < 10^{-4}$. The H_2O mixing ratio is evidently not the same at different altitudes. The results of a spectrophotometric experiment carried out by the "Venera-13"

and "Venera-14" on 1 and 5 March 1982 fully confirmed the above and other conclusions drawn in this article. Figures 16, tables 6; references 50: 29 Russian, 21 Western.
[2-5303]

UDC 550.388:523.42

FORMATION OF PLASMA MANTLE IN VENUSIAN MAGNETOSPHERE

Moscow KOSMICHESKIYE ISSLEDOVANIYA in Russian Vol 20, No 4, Jul-Aug 82 (manuscript received 24 Jul 81) pp 604-619

ZELENYY, L. M. and VAYSBERG, O. L.

[Abstract] The authors make a number of quantitative evaluations characterizing the process of flow of the solar wind around Venus and compare them with the results of measurements on the "Venera-9," "Venera-10" and "Pioneer Venus." Emphasis is on formation of the plasma-ionospheric mantle in the induced magnetosphere because this region is crucial for comprehending the physics of flow of the solar wind around Venus. The formation now known as the mantle was discovered by the "Venera-9" and "Venera-10" in the form of a stream of ions with an energy of directed motion 100-200 eV and a temperature of 1-10 eV usually filling a considerable part of the Venusian tail. The electron component of this plasma formation registered by the "Pioneer Venus" on the daytime side of the planet fills a region approximately coinciding with the region of the magnetic barrier. These basic facts and the considerable theoretical and analytical work done since that time has enabled the authors to propose a model of interaction between the solar wind and Venus which takes into account all aspects of formation of the magnetic barrier and formation of the Venusian tail. The exposition of these materials is in 5 sections: formation of the magnetic barrier in the frontal part of the induced magnetosphere; photoproduction of plasma in magnetic barrier; convection of photoplasma in Venusian magnetosphere; plasma mantle and formation of magnetotail; role of plasma processes in formation of plasma mantle in Venusian magnetosphere. It is evident that the source of the plasma mantle may be the photoions forming in the magnetic barrier and experiencing convection into the tail under the influence of the gradient of magnetic pressure and magnetic tension. The formation of the magnetic tail is determined by the convection of tubes of force from the magnetic barrier, in which the solar wind plasma is replaced by ions of planetary origin. The model gives ion velocity values and a thickness of the magnetic barrier at the terminator which are somewhat greater than indicated by observational data and a particle concentration and magnetic field strength in the tail which are somewhat less than the observational data, indicating a possible role of anomalous ionization in the process of interaction between the solar wind and Venus. Figures 3; references 28: 9 Russian, 19 Western.
[2-5303]

UDC 523.33:523.42

COMPOSITION OF VENUSIAN DAYTIME ATMOSPHERE AT 110-200 KM

Moscow KOSMICHESKIYE ISSLEDOVANIYA in Russian Vol 20, No 4, Jul-Aug 82
(manuscript received 2 Feb 82) pp 647-650

KRASNOPOL'SKIY, V. A.

[Abstract] The author has constructed a model of the Venusian daytime atmosphere at 110-200 km at the time of increased solar activity on the basis of available experimental data and a series of theoretical premises. The choice of the lower boundary at 110 km was dictated by the fact that chemical reactions in the atmosphere become significant at lower levels. Above 110 km the only role is played by transfer processes and also the generation and annihilation of components as a result of photolysis. Computations were made with $z_{\odot} = 60°$. In the considered altitude range the distributions of concentrations of all pertinent components are described well by an exponential dependence with the scale height $H_i(z)$; the problem is reduced to finding $H_i(z)$. There is no problem for CO_2 since HCO_2 is determined by $T(z)$; the problem is somewhat more complex for N_2. Using the formulas derived in this article it is possible to compute the vertical profiles of components in the upper atmosphere without using a computer. Computations of the concentrations of all components are made for one altitude and then it is necessary to repeat these computations at the next level. The computed CO_2, O, CO, N_2, O_2 profiles are represented in a figure for $K = 10^{13}$ $M^{-1/2}$ cm^2/sec. The computations for O and CO agree well with American satellite measurements. The data for the atmospheric model are summarized in a table; data are given separately for altitudes 110, 120, 130, 140, 150, 160, 170, 180, 190, 200 km. Figures 1; tables 1; references 10: 3 Russian, 7 Western.
[2-5303]

UDC 523.33:523.43+523.42

ATOMIC CARBON IN MARTIAN AND VENUSIAN ATMOSPHERES

Moscow KOSMICHESKIYE ISSLEDOVANIYA in Russian Vol 20, No 4, Jul-Aug 82
(manuscript received 3 Feb 82) pp 595-603

KRASNOPOL'SKIY, V. A.

[Abstract] An article with this same title was published 11 years ago by M. V. McElroy and J. C. McConnell (J. GEOPHYS. RES., Vol 76, p 6674, 1971). Since that time new and more precise data have been published on the processes of formation of C from CO and CO_2. The models of the Martian and Venusian atmospheres have also been improved and therefore it was deemed timely to reassess the entire problem. Computations of the concentrations of atomic carbon require data on four atmospheric components: CO_2 , CO,

O and O_2. Figures 1 and 2 show models of the Martian and Venusian atmospheres and the results of computations of the concentrations of atomic carbon at the time of increased solar activity. Figures 3 and 4 illustrate the results of computations of the processes of C and C* formation on Mars and Venus. It is shown that the production of C and C* on Venus is tens of times greater than on Mars. The principal reason for this is that the flux of solar radiation on Venus is 4.5 times greater. It also loads to increased CO and O concentrations. The efficiency of the processes of freeing of the C atom in CO on the average is an order of magnitude greater than in similar processes in CO_2. These two factors explain the great difference in the production of C and C* on Mars and Venus. In computing the C concentration it is necessary to know the reactions of C annihilation and their rate coefficients. On Mars the concentration maximum is at 155 km where $[C] = 1.5 \cdot 10^5\ cm^{-3}$; on Venus it is at 145 km where $[C] = 7 \cdot 10^6\ cm^{-3}$. The total quantity of C atoms in a vertical column is $N_C - 1.2 \cdot 10^{12}\ cm^{-2}$ on Mars and $2.3 \cdot 10^{13}\ cm^{-2}$ on Venus. Saturation effects are substantial in the case of resonance scattering of 1657 A. The main contribution to the glow is from excitation processes during C formation. The zenith intensity of the glow is 50 rayleigh on Mars and 420 rayleigh on Venus. The intensity at the maximum at the limb is 1.6 kilorayleigh on Mars and 20 kilorayleigh on Venus. Figures 6; references 31: 3 Russian, 28 Western.
[2-5303]

UDC 523.4

PRELIMINARY RESULTS OF MASS-SPECTROMETRIC MEASUREMENTS BY 'VENERA-13,' 'VENERA-14' DESCENT VEHICLES

Moscow PIS'MA V ASTRONOMICHESKIY ZHURNAL in Russian Vol 8, No 7, Jul 82 (manuscript received 6 May 82) pp 391-398

ISTOMIN, V. G., GRECHNEV, K. V. and KOCHNEV, V. A., Institute of Space Research, USSR Academy of Sciences, Moscow

[Abstract] The MKh-6411 radio-frequency mass spectrometers used in the "Venera-13" and "Venera-14" descent vehicles were an improved version of the one previously used. Their operating principle was ion selection by the rate of transit. The authors list the instrument's characteristics, then interpret the information obtained about minor admixtures in Venus's atmosphere from an altitude of 26 km down to the surface. The results are: neon-20--about 10 parts per million; ratio of neon-20 to neon-22--from 11.7 ± 0.7 to $14.3^{+5.7}_{-3.2}$; ratio of neon-22 to neon-21--more than 10; nitrogen--4 vol. %; argon--100 parts per million; ratio of argon-36 to argon-38--close to 5.35; krypton--10-100 parts per billion; sum of isotopes xenon-131 and xenon-132--10-100 parts per billion. Figures 7; references 15: 4 Russian, 11 Western.
[34-11746]

UDC 523.4

GAS CHROMATOGRAPH ANALYSIS OF CHEMICAL COMPOSITION OF VENUS' ATMOSPHERE BY 'VENERA-13,' 'VENERA-14' DESCENT VEHICLES

Moscow PIS'MA V ASTRONOMICHESKIY ZHURNAL in Russian Vol 8, No 7, Jul 82 (manuscript received 6 May 82) pp 399-403

MUKHIN, L. M., GEL'MAN, B. G., LAMONOV, N. I., MEL'NIKOV, V. V., NENAROKOV, D. F., OKHOTNIKOV, B. P., ROTIN, V. A. and KHOKHLOV, V. N., Institute of Space Research, USSR Academy of Sciences, Moscow

[Abstract] The authors describe the functioning of the "Sigma-2" gas chromatographs used to analyze the composition of Venus' atmosphere from on board the "Venera-13" and "Venera-14" descent vehicles. The following substances were identified and measured (in volumetric percentages, followed by the altitude, in kilometers, at which the samples were taken): H_2—$(2.5 \pm 1) \cdot 10^{-3}$, 58-49; O_2--$(1.8 \pm 0.4) \cdot 10^{-3}$, 58-35; Kr—$(7 \pm 3) \cdot 10^{-5}$, 49-37; H_2O—$(7 \pm 3) \cdot 10^{-2}$, 58-49; H_2S--$(8 \pm 4) \cdot 10^{-3}$, 37-29; COS—$(4 \pm 2) \cdot 10^{-3}$, 37-29; SF_6—$(2 \pm 1) \cdot 10^{-5}$, 58-3.5. The authors also state that further processing of the chromatographs will make it possible to determine the amount of HCl in the atmosphere and to refine the figures for the hydrogen and sulfur compounds. Figures 6; references 5: 3 Russian, 2 Western.
[34-11746]

UDC 550.35:523.45

SPECIAL FEATURES OF FORMATION OF JUPITER'S OUTGOING THERMAL RADIATION

Moscow KOSMICHESKIYE ISSLEDOVANIYA in Russian Vol 20, No 3, May-Jun 82 (manuscript received 4 Jan 81) pp 449-459

KAZMENKO, S. V. and TIMOFEYEV, Yu. M.

[Abstract] The authors present the results of calculations of the spectrum of Jupiter's outgoing thermal radiation in the 10-1,000 cm^{-1} band for numerous models of the atmosphere and compare them with the available experimental data. They substantiate their choice of the 10-1,000 cm^{-1} band, calculate the spectra for the different models, and then try to resolve discrepancies between their results and the experimental data. They also make a preliminary selection of channels to be used in actual experimental sensing and analyze the accuracy of their solutions. They reach several conclusions on the basis of the comparison of their experimental models and the available experimental data, but say that further research is necessary to refine the physical and radiation models of Jupiter's atmosphere. The authors also state that their indirect method yields results with 1-3 K accuracy, but only if our present concept of Jupiter's atmosphere is correct. Figures 5; references 36: 12 Russian, 24 Western.
[113-11746]

UDC 521.15

DYNAMICS OF FORMATION OF RESONANCE ROTATIONS OF NATURAL CELESTIAL BODIES

Moscow ASTRONOMICHESKIY ZHURNAL in Russian Vol 59, No 4, Jul-Aug 82
(manuscript received 8 May 81) pp 769-778

KHENTOV, A. A., Gorkiy State University

[Abstract] The author discusses the fundamental aspects of questions concerning the formation of synchronisms between the periods of rotation of large bodies in the Solar System and many bodies with periods of rotation that are synchronized with their orbital motion. Assuming that the most important role in the evolution of the dynamic characteristics of the large bodies at some point after their formation was played by gravitational and tidal moments, he concludes that the process of evolution of rotation is still continuing for some of them. Another conclusion is that it is not very likely (or is even impossible) to detect synchronisms other than 1:1 or 3:2 for bodies in the Solar System, since the large bodies in it have little orbital eccentricity. After a brief analysis of the available data on Venus, the author concludes that it is most likely not held in resonance rotation. Figures 5; references 25: 22 Russian, 3 Western.
[30-11746]

LIFE SCIENCES

ACADEMICIAN TROITSKIY ON SEARCH FOR EXTRA-TERRESTRIAL INTELLIGENCE

Leningrad LENINGRADSKAYA PRAVDA in Russian 2 Nov 82 p 3

[Interview with Academician V. S. Troitskiy: "Extra-Terrestrial Civilizations: The Search Has Not Ended"]

> [Text] One of the groups of Soviet scientists who for 15 years already have been searching for signals from extraterrestrial civilizations is led by V. S. Troitskiy, deputy director of the Gorkiy Scientific Research Radio-Physics Institute, and corresponding member of the USSR Academy of Sciences. Correspondent O. Borisov converses with him.

[Question] Vsevolod Sergeyevich, for many years now radio astronomers, mainly Soviet and American, have been searching the skies eagerly, trying to isolate out of the inconceivable chaos of cosmic rays the signals of far off civilizations. And—nothing! This year at the symposium in Tallinn dedicated to the search for intelligent life in the universe, dozens of reports were given, but no matter that aspect of the problem they concerned, in the meeting hall there hung constantly the invisible sacramental question: Why do "they" not answer?

[Answer] The situation surrounding this problem has been somewhat dramatized in recent years. Thus far no one has succeeded in isolating signals of a deliberately artificial origin. Apparently, no spacecraft from foreign solar systems are traveling around in the galaxy either, or otherwise they could have been detected. For interstellar voyages they would have to expend only one ten-thousandth of the Sun's total radiation energy, and with the aid of modern apparatus this level of radiation could be noticed. This "silence," the absence of any miracles from the cosmos, has even created the impression among some researchers that the earth's civilization may be the only one in our galaxy, and perhaps in the entire universe.

Meanwhile, recently conducted experiments show that outer space is silent because we still listen to it very crudely. In addition, the search strategy taken thus far is based on premises which are most likely in part erroneous. I will clarify this. According to the conventional classification of USSR Academy of Sciences Corresponding Member N. Kardashev, it was customary to divide hypothetical extra-terrestrial civilizations into three types. The first is like the earth, with a similar level of technological development and energy consumption. The second is a civilization which has mastered billions of times more energy—the energy of its star. Finally, the third type is a super-civilization which controls the energy of its galaxy.

Let us discuss this. Suppose that for sime group of stars, civilizations arise and achieve a high level of technological development. In principle, nothing will prevent them from at some time beginning to colonize the whole galaxy. However, this can be done only in stages. Let us say that a vessel with several thousand intelligent inhabitants is launched toward the neighboring stars. After many years it will reach the appropriate planet and create a new island of civilization. The regeneration of a new, multi-million person society with powerful industry and huge energy reserves must be accomplished over the course of the next hundreds and thousands of years. Only after this can they start out for new, still more remote stars. And again there will be the time enroute, new reproduction, and a new departure. Scientists' calculations show that something on the order of 10 million years may be needed to assimilate the expanses of the galaxy in this manner.

And with respect to this we come to the next interesting conclusion. If the rise of civilizations is an orderly process, and if even part of them achieve a high level of development, then after 10 billion years of a galaxy's existence, these "older brothers" in intelligence may have colonized this entire solar system many times, and may in the past have been to the planet Earth many times. But until now (proceeding from a strictly scientific basis) we have no convincing evidence of their presence on our planet. This means that we have no basis to count on the presence in our galaxy of some super-civilization. This is on the one hand.

On the other hand, the laws of nature themselves place a ban in principle on the existence of a civilization of galactic scale. In particular, the ultimate speed of signal dissemination (the speed of light) does not permit mutual ties to be implemented over the colossal expanses of the galaxy (tens of thousands of light years!) in order to permit exchange of information, mass and energy between the islands of intelligence which are settling it. Without mutual and reciprocal ties any communications is unthinkable.

A very important conclusion derives from this: We must not count on receiving very powerful artificial signals, easily intercepted by our equipment, since those who might send them—super-civilizations—simply do not exist.

Thinking more deeply about the problem, we begin to understand that for civilizations of the second type also, to transmit simultaneously over a long period of time to all the stars in the galaxy (that is with the aid of an omni-directional antenna) is an unbelievably difficult task. It would require a spherical antenna the size of the earth, and enormous transmission power—10^{23} watts. For comparison, I remind you that earth's entire civilization at this time produced 10 billion times less energy. But even at this level of production, as we know from our own experience, the planet's energy resources even for internal needs are highly limited. So why would other civilizations be so wasteful as to spend the lion's share of their energy on protracted interstellar communications?

Thus, we must be prepared for the communications sessions to occur either over extremely short intervals of time, or, if the transmissions are protracted, to be at much lower power levels. Consequently, for us the sky is silent, in particular either because we do not know the communications schedule, or the level of signals reaching the earth is too weak for the radio-telescopes which we now have.

Appropos of this, the illusion of cosmic silence may stem from a situation in which civilizations are only beginning to arise in our galaxy, and the level of their technological development does not differ much from that achieved by earthlings. Consequently, they do not possess energy sources to enable them to send sufficiently powerful signals. That is why we should increase the sensitivity of our receivers by 10,000-100,000 times. To do this it is necessary to increase the antenna area by many thousands of times over that now existing. It would be most advisable to develop such structures in space. I note that the first projects for such large space radio-telescopes are already being worked out in our country.

[Question] The search for signals from alien space civilizations has been going on under your leadership since 1968 from the Gor'kiy Scientific Research Radio Physics Institute. How has this been done thus far? With what results? And what are your plans for the future?

[Answer] During these years we have been receiving at wave lengths of 21 centimeters, 50 centimeters, and 1 meter on an omnidirectional antenna. The advantage of such an antenna is that at any given moment of observation the entire hemisphere of the sky can be heard. The shortcoming is that it is not possible to localize the source of emanations, and the receiver is not very sensitive. Therefore, we can only count on hearing very powerful signals, such as from a civilization of the second type. The telescope has been in operation around the clock, with interruptions only in cold periods, due to the conditions of observation. Thus far we have not succeeded in detecting any call signs from other worlds. But his does not mean that our efforts have been wasted. We have extensive statistics on the emanations which have been received, and, by the nature of the signals which have been registered, we can sufficiently reliably judge "what's what."

A more modern antenna, which is better suited to our purposes, should be introduced in the next year-and-a-half or two years. It will be a fan or a multi-wire antenna. As before, the diagram of its direction will encompass the entire hemisphere, but in the event that a "suspicious" signal is intercepted, it will be possible to determine from which section of the horizon the interesting signal came. And the sensitivity of the radio-telescope will increase by 1000 times. This is still not so much, but from a distance of 300-500 light years reception will be sufficiently reliable. And millions of stars in our galaxy are within a sphere of this radius.

It is completely possible that we will not intercept artificial extraterrestrial signals for yet another 10, 20 or 30 years, for this is truly a task of terrible difficulty. But this in no way would mean that "they" truly do not exist, but that in our ability to intercept, we have still not reached the level corresponding to the magnitude of the problem to be resolved. It is so grandiose in its essence, that it requires a serious approach and courageous ideas. In any case we must continue.

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CSO: 1866/59

SPACE ENGINEERING

SPACE PROPULSION UNITS OF FUTURE

Moscow KOSMICHESKIYE DVIGATELI BUDUSHCHEGO (NOVOYE V ZHIZNI, NAUKE, TEKHNIKE: SERIYA "KOSMONAVTIKA, ASTRONOMIYA") in Russian No 3, Mar 82 pp 2-31, 64

[Annotation, table of contents, introduction and chapter "Self-Contained Propulsion Systems" from book "Space Propulsion Units of the Future (Advances in Life, Science, Technology: Series 'Cosmonautics, Astronomy')", by Aleksandr Sergeyevich Dmitriyev and Vladimir Alekseyevich Koshelev, Izdatel'stvo "Znaniye", 26,400 copies, 64 pages]

[Text] This short book makes an attempt to present all possible directions in the development of the space propulsion systems of tomorrow. It examines a number of traditional and new ideas and plans concerned with space propulsion units, their potentials and their correspondence to the tasks which, by today's reckoning, will become the most important in the not very remote future.

This book is intended for a broad range of readers.

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The Right to be Born and to Survive 58

Introduction

Two and a half decades separate us from 4 October 1957, a date destined to divide mankind's history into two ages--prespace and space. The generation which was born and which grew up during this time obtained its rudimentary knowledge of space not from the novels of Jules Verne but from almost daily messages from telegraph agencies, television reports and newsreels.

Today, hundreds of thousands of people in laboratories, scientific centers, design offices, plants and factories are "employed" by space to one extent or another. It has long ceased being a sensation, but it has become something very necessary. Manned craft, space communication resources, meteorological satellites and navigation systems are going a long way to define the countenance of our times.

At the same time, there is good reason for saying that the roads to space are hard. On them, things do not always happen as we might want. Our ideas on the priorities of the conquest of space changed radically in the past two and a half decades. The "main" line of development of cosmonautics--"Moon, Mars and then all points beyond," one which seemed to be obvious not only to hobbyists and science fiction buffs but also to specialists, has undergone significant transformation with a consideration for the needs and possibilities of society. A number of plans, for example, manned flight to Mars, were found to be on the border of those which are technically feasible given the present level of development of space technology but which are at the same time beyond the border of the outlays that would be economically permissible for these purposes.*

The very fact that we have rejected the further pursuit of the "main" direction tells us that space and space industry have transformed into a highly significant factor, not only an emotional and a political one, but also an economic one. Further increases in outlays become justifiable only in the event that a return which would compensate for a significant part of the investments could be anticipated. The demand that space programs pay for themselves in economic terms is going a long way to define the directions of development of cosmonautics in general in this new stage.

This short book makes an attempt to present the possible directions of development of space propulsion systems of tomorrow. Naturally there are always numerous variants of solving the same problem in a complex and difficult program such as the creation of space vehicles. Moreover the arsenal of technical ideas and possibilities is constantly being replenished, and many of the new concepts may turn out to be somehow better than those of which we are aware today. Therefore readers who would wish to hear a clear answer as to what sort of propulsion units space vehicles will have in, let us say, 30-40 years, will probably be disappointed. This book does not contain an unambiguous answer to this question; moreover such an answer would hardly be possible. It examines a number of traditional and new ideas and plans concerned with space propulsion units, their potentials and their correspondence to the tasks which, by today's reckoning, will become the most important in the not very remcte future.

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*We should note that the program to put man on the moon has already cost about $24 billion. The cost of a Mars expedition, meanwhile, is estimated at $70-80 billion.

From the standpoint of the prospects of space propulsion unit construction, the main directions in development of space technology may be conditionally divided into four groups.

1. Organization of considerable freight traffic (tens and hundreds of thousands of tons per year) from the surface of the earth to low orbits. Today's freight traffic is about one-tenth of that. We must significantly increase the freight traffic if we are to complete fundamentally new tasks (in particular, create industrial production operations and power supply systems in outer space) and if we are to insure continuation of research in outer space.

2. Transportation of large cargoes from low orbits to high orbits and back, and transportation of similar cargoes from near-earth orbit to the moon. For most tasks, getting a space vehicle into a holding orbit is the intermediate stage. Communication satellites, the power supply systems mentioned above and many other space vehicles must be located on high orbits. Thus the demand for economical resources for interorbital flights is growing.

3. Fast interplanetary flights.

4. Creation of space vehicles to fly beyond the Solar System, and the launching of space vehicles to the closest stars.

For classification purposes, the space propulsion units examined in this book are conditionally divided into three groups: 1) self-contained, in which the energy source and the working medium are contained aboard; 2) propulsion systems with external energy systems and 3) propulsion systems using external sources of mass as the working medium.

The first group includes liquid and other chemical rocket engines and nuclear and thermonuclear engines; the second includes space propulsion units in which acceleration is imparted to the working medium by energy from lasers or superhigh-frequency generators located outside the spacecraft, and propulsion units making use of the sun's energy in one way or another. Finally, the third group contains propulsion units in which the atmosphere, the interplanetary medium and rock from planets and asteroids are used as the working medium.

Self-Contained Propulsion Systems

Possibilities of Self-Contained Propulsion Systems

The role played by a rocket engine is to transform some form of energy into the rocket's kinetic energy. In correspondence with the well-known principle of jet propulsion, this transformation may be achieved by ejecting auxiliary mass--that is, by imparting a certain velocity to the engine's working medium. Thus every propulsion system must include a source of energy, a source of ejected mass (the engine's working medium) and the engine itself--a device in which the energy of the source is transformed into the kenetic energy of the working medium.

In some engine designs the energy source and the working medium may be combined. For example in liquid-propellant rocket engines (LREs) energy is emitted due to a chemical reaction between the components of the working medium. But if the energy source and the working medium are located aboard the rocket, such propulsion systems are called self-contained.

It follows from the law of conservation of energy that the minimum reserve of energy contained aboard a rocket must be equal to the sum of the kinetic energy of the payload and the work done to surmount gravity and air resistance as the rocket is being launched from earth surface. For example the energy outlay required to place a mass of 1 kg in an artifical satellite into an orbit 300 km high is $4.5 \cdot 10^7$j.

Inasmuch as work must also be done to accelerate the energy source, it would be desirable to use sources which would emit maximum energy per unit mass. Energy may be stored in the most diverse forms--mechanical, electric, magnetic, chemical and nuclear. The best characteristics are possessed by energy sources making use of chemical and nuclear reactions.

Table 1 shows the specific energies of reactions used today and reactions that may be used in the future.

Table 1. Parameters of Energy Sources for Different Types of Rocket Engines

Параметры источников энергии
(1) **для различных типов ракетных двигателей**

(1) Источники и используемые реакции	(2) Энерговыделение, МДж/кг	(3) Скорость истечения, км/с	(4) Удельная тяга, с
(5) Химические реакции:			
1) $2H_2 + O_2 = 2H_2O$	10	4,5	456
2) $H_2 + F_2 = 2HF$	11,5	4,8	490
(6) Реакции свободных радикалов ($H + H = H_2$)	436	29	3000
(7) Радиоизотопные источники энергии ($Po^{210} \longrightarrow Pb^{206}$)	$5 \cdot 10^6$	10^3	10^5
(8) Ядерные реакции деления ($U^{235} \longrightarrow$ 2 осколка) (9)	$8 \cdot 10^7$	$12,6 \cdot 10^3$	$12,8 \cdot 10^5$
(10) Ядерные реакции синтеза ($Д + T \longrightarrow He^4_2 + H$)	$3,36 \cdot 10^8$	$2,59 \cdot 10^4$	$2,64 \cdot 10^6$
(11) Аннигиляция вещества ($p^+ + p^- \longrightarrow \gamma$)	$9 \cdot 10^{10}$	$3 \cdot 10^5$	$3 \cdot 10^7$

Key:

1. Sources and reactions employed
2. Energy liberated Mj/kg
3. Exhaust velocity, km/sec
4. Specific thurst, sec
5. Chemical reactions
6. Free radical reactions
7. Radioisotope energy sources
8. Nuclear fission reactions
9. Fragments
10. Nuclear fusion reactions
11. Annihilation of matter

We might conclude from this table that to place a satellite weighing 1 kg into earth orbit, the amount of energy liberated from reaction of an oxygen-hydrogen mixture weighing 3.5 kg or from fission of uranium-235 weighing 0.5 mg would be sufficient. However, complete transformation of energy carried aboard a rocket into the latter's kinetic energy is practically impossible.

The reason for this is that the efficiency with which stored energy is converted into the kinetic energy of the working medium is always less than 100 percent.

Part of the energy (the greater part in the case of electric motors) is scattered uselessly in space in the form of thermal radiation, while another part is carried away in the form of the intrinsic energy of the ejected mass (heat, energy of dissociation etc.). These losses are what determine the efficiency of a propulsion unit.

Second, complete utilization of the kinetic energy of the ejected mass would be possible only in the event that its velocity is opposite and equal to the velocity of the rocket--that is, if this mass remains motionless relative to the starting point of the rocket after it leaves the engine. Losses stemming from the difference in absolute values of the velocities of the ejected mass and the rocket are what define the so-called thrust efficiency.

Figure 1 shows a diagram of the energy balance of different rocket engines. The relative loss values are given for the LRE and for an electric motor (in parentheses).

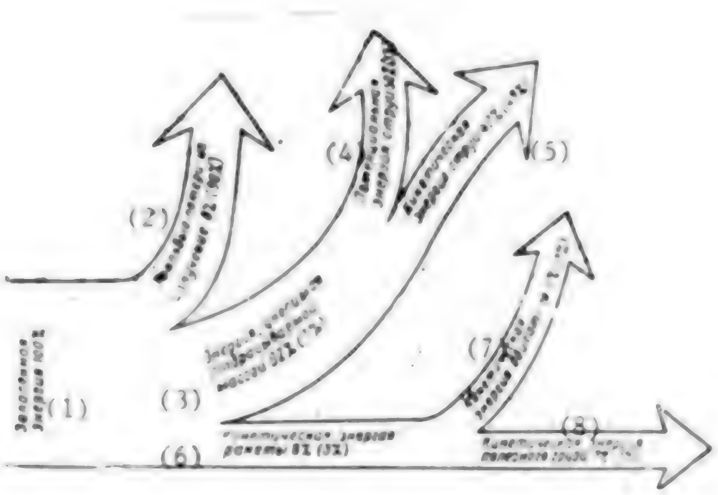

Figure 1. Energy Balance of the Propulsion System of an LRE and an Electric Motor (in parentheses)

Key:
1. Stored energy 100%
2. Thermal emission losses 8% (90%)
3. Energy carried away by ejected mass 92% (7%)
4. Jet potential energy 50% (3%)
5. Jet kinetic energy 42% (49%)
6. Rocket kinetic energy 8% (3%)
7. Engine kinetic energy 1% (2%)
8. Payload kinetic energy 7% (1%)

Work done by a rocket engine per unit mass of the rocket is the square of the velocity, which is why a certain characteristic velocity--v_c--is conveniently employed as a measure of this work. When a rocket accelerates in the vacuum of space, in the absence of gravitational fields, this velocity coincides with the rocket's own velocity. Correspondingly the work done to accelerate the working medium in the engine may be expressed by its velocity--the so-called exhaust velocity--v_e.

The dependence between these velocities, given a constant exhaust velocity, is described by Tsiolkovskiy's equation, $v_c = v_e \ln (1 + z)$, where z is Tsiolkovskiy's number, equal to the ratio of the mass of the working medium stored aboard the rocket to the mass of the "empty" rocket (to include the mass of the payload, engine and structure).

The characteristic velocity is usually expressed by the corresponding velocities associated with the outlays of energy necessary to complete some particular task. They include escape velocity, orbital velocity and, if a planet is to be approached as one of the purposes of the flight, the planetary closing-in velocity. For the launching of an artificial earth satellite, for example, the characteristic velocity is 9.5 km/sec, escape velocity is 12.5 km/sec, and the velocity for interplanetary flights is 30-50 km/sec.

Tsiolkovskiy's number is the most important characteristic of a rocket: For a given payload weight, it determines the launch weight of the rocket, and therefore it would be desirable to have it as small as possible. It follows from Tsiolkovskiy's equation that for a given characteristic velocity, Tsiolkovskiy's number may be decreased only by increasing the exhaust velocity. Thus the exhaust velocity is one of the main characteristics of an engine, and increasing it is the most important task of improving rocket engines.

Using the definition of exhaust velocity for engines with combined energy sources and ejected mass, where the working fluid is accelerated by the action of its intrinsic energy, it would be easy to calculate the exhaust velocity by equating the kinetic energy of the ejected mass to its intrinsic energy multiplied by the engine efficiency. Table 1 shows the exhaust velocities corresponding to different kinds of reactions in an engine with an efficiency of 100 percent.

Figure 2 is a graph of the dependence between characteristic velocity and exhaust velocity for different Tsiolkovskiy numbers. Comparing this graph with Table 1, we can conclude that it would be easy to complete all space flight missions by using uranium-235 as rocket fuel, not to mention deuterium and tritium. And in fact, before a characteristic velocity of 30 km/sec, which would be necessary for flight to the planets, and given an exhaust velocity corresponding to the fission energy of uranium, Tsiolkovskiy's number would be $5.5 \cdot 10^{-3}$. Even at an efficiency of 1 percent the ratio of the mass of the uranium to the mass of the rocket would be only 0.056.

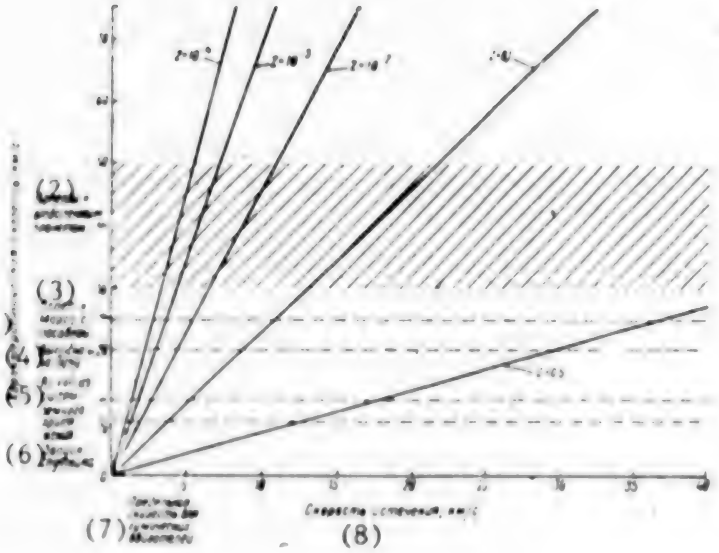

Figure 2. Dependence of Characteristic Velocity on Exhaust Velocity for Different Tsiolkovskiy Numbers

Key:

1. Characteristic velocity, km/sec	5. Escape from earth's gravity
2. Flights to distant planets	6. Launching a satellite
3. Landing on Mars	7. Maximum velocity for chemical engines
4. Landing on the moon	8. Exhaust velocity, km/sec

However, all atoms of the uranium must react if the calculated exhaust velocity is to be achieved in the engine. Inasmuch as not less than something known as the critical mass of the dividing substance (about 1 kg for uranium) must be present to self-maintain a nuclear fission reaction, in this case an enormous amount of energy would be liberated in the engine in about 10^{-6} sec--10^{15}j. Conversion of even part of this energy into the rocket's kinetic energy within such a short of period of time would correspond to excessively large accelerations, ones which could not be withstood by any rocket design. Moreover, the reaction products have a temperature of more than 50 billion degrees Kelvin, and their interaction with the engine walls would cause the latter's thermal breakdown.

In the case of a moderated controlled nuclear reaction, one occurring in an atomic reactor, the fission fragments lose their energy by colliding with unreacted atoms, the concentration of which is several orders of magnitude greater, and on the whole the dividing substance would acquire energy much less than the specific energy of a nuclear reaction. It would be disadvantageous to utilize this energy to impart exhaust velocity to the dividing material itself, since too much energy would be lost in the form of the intrinsic energy of unreacted nuclei, and consequently the engine efficiency would be impermissibly low.

Because of the limitations imposed upon use of nuclear reactions in rocket engines, the first suggestion is to transmit the energy to a neutral mass stored aboard the rocket--that is, the energy source and ejected mass are made separate.

The following fundamental difference in the requirements on exhaust velocity for these engines and for engines in which the working medium is simultaneously the energy source should be noted. A flight mode characterized by a constant exhaust velocity described by Tsiolkovskiy's equation would be disadvantageous from the standpoint of thrust losses (the thrust efficiency is 100 percent only at that point in the trajectory where the exhaust velocity is equal to the rocket velocity). And in fact, as follows from Figure 1, for a typical engine having a constant exhaust velocity (an LRE) the losses connected with the kinetic energy of ejected mass are about half of the total losses.

However, it follows from an analysis of the rocket motion equation that for an engine utilizing the intrinsic energy of the working medium as its energy source, a minimum value is insured for Tsiolkovskiy's number irrespective of the characteristic velocity, assuming that the maximum possible exhaust velocity for this engine is achieved. But in engines where the energy source is separate from the ejected mass, the acceleration conditions of rockets having a constant exhaust velocity are no longer optimum, and thrust efficiency can be raised only by significantly improving the rocket charactertistics. In this case exhaust velocity must increase in proportion to rocket velocity.

The dependence describing concrete values of exhaust velocity is rather complex, and we will not dwell on it here. Moreover engines with variable exhaust velocity are difficult to design in practice. Therefore engines with the energy source separated from the ejected mass would best be described by a certain mean exhaust velocity.

The minimum energy stored aboard a rocket (it can be characterized, as an example, by the weight of uranium-235) is achieved at an exhaust velocity approximately equal to 62 percent of the characteristic velocity and with a Tsiolkovskiy number equal to 4. And on the other hand if the energy stored aboard the rocket and the characteristic velocity are given, then the optimum exhaust velocity would correspond to the maximum possible payload of the rocket.

Hence it follows that in engines with separate energy sources and ejected mass, the exhaust velocity must not exceed an optimum value determined by the concrete mission of the space flight. This position is not contradictory to the assertion made above that we must try to raise exhaust velocity in the design of new engines, since for most missions, the optimum exhaust velocity has not yet been achieved in existing engine designs.

In some cases it would be advantageous to reduce exhaust velocity by adding inert mass, even in engines utilizing the intrinsic energy of the working medium. For example a rocket with an LRE taking off from the moon must impart a characteristic velocity of about 2.5 km/sec to the payload. But the optimum exhaust velocity for this particular task is 1.6 km/sec (0.62 v_c). An LRE has a significantly larger exhaust velocity, and therefore it would be advantageous to reduce it to optimum by adding lunar dust to the working medium (desirably those components of lunar dust which would vaporize at the engine's operating temperature), if the rocket possesses empty tanks that were freed during its landing on the moon.* As a result of this operation the payload may be increased by 20-50 percent depending on the kind of rocket propellent employed.

Another important parameter which we use to compare rocket engines is thrust--that is, the force created by the engine to accelerate the rocket. Thrust is equal to the product of the amount of ejected mass (engine working medium) consumed per second and the exhaust velocity. This parameter is used to distinguish between high-thrust engines, for which the thrust exceeds the weight of the rocket and the latter can be launched from the surface of the earth, and low-thrust engines suitable only for launching a satellite that is already in orbit.

Division of engines into low- and high-thrust engines is directly associated with yet another parameter--the specific mass of the engine, which is equal to the ratio of the weight of the engine to the thrust it develops. Naturally engines with a specific weight greater than unity must be classified as low-thrust engines.

Let us now examine future designs of self-contained engines and the methods of improving the existing designs from the standpoint of the examined parameters, and primarily exhaust velocity.** However, we should note first of all that two basic classes of rocket engines can be distinguished in terms of the method used to transform energy into the kinetic energy of the ejected mass--thermal and electric (Figure 3). Moreover there also exist explosive, photon and other kinds of engines.

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*Of course, were reserves of rocket propellents present on the moon, filling the empty tanks with them would produce an even greater payoff in payload. But such refueling would be equivalent to increasing the onboard energy store, and therefore the ideas presented here concerning optimum exhaust velocity would be irrelevant.

**In rocket technology, another concept equivalent to exhaust velocity is used to describe engines--specific thrust (specific impulse), which is numerically equal to exhaust velocity divided by freefall acceleration (9.81 m/sec^2), and it is correspondingly measured in seconds. Specific thrust corresponds to the thrust generated as a result of consumption of working medium weighing 1 kg in 1 sec. We will subsequently use this concept in addition to exhaust velocity. Specific thrust values for some working mediums were given in Table 1.

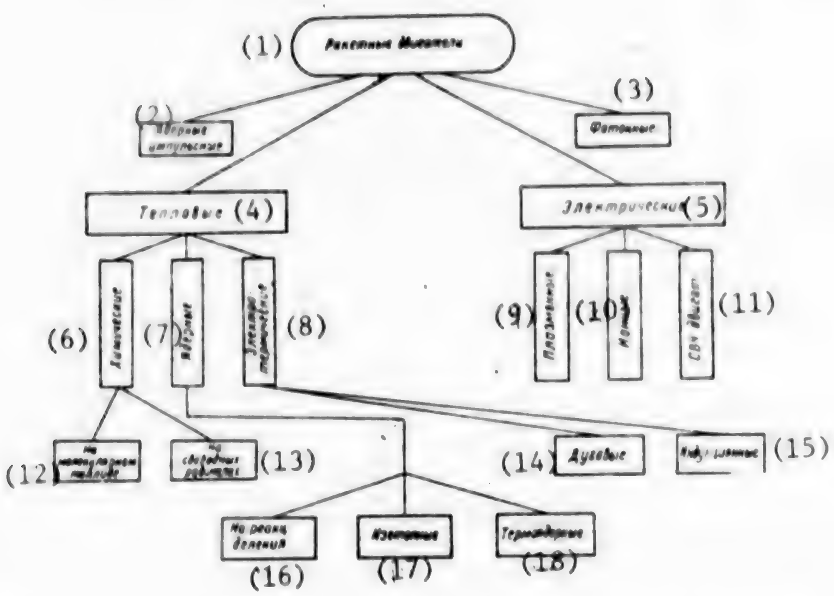

Figure 3. Classification of Self-Contained Engines

Key:

1. Rocket engines
2. Nuclear impulse
3. Photon
4. Thermal
5. Electric
6. Chemical
7. Nuclear
8. Electrothermal
9. Plasma
10. Ion
11. Superhigh-frequency engines
12. Using molecular propellent
13. Using free radicals
14. Arc
15. Induction
16. Using fission reaction
17. Isotope
18. Thermonuclear

Thermal Engines

As is the case with all thermal machines (gas turbines, internal combustion engines), the main energy conversion mechanism in thermal engines is expansion of a gas that is first compressed and heated to high temperature. The device which causes this conversion is the jet nozzle (a shaped channel with variable cross section), through which the working fluid is exhausted into external space.

The exhaust velocity at the nozzle exit is directly proportional to the square root of the temperature of the working medium, and it is inversely proportional to its molecular weight. The thermodynamic efficiency of a nozzle operating as a thermal machine is defined as the difference between the gas temperatures at the entrance and the exit from the nozzle, which in turn depends on the relative pressure gradient--that is, it depends on the degree of gas expansion. The degree of gas expansion is limited by the dimensions and weight of the engine, and therefore the thermodynamic efficiency of real structures does not exceed 60-70 percent.

Thus there are only two possibilities for improving the characteristics of thermal rocket engines--raising the temperature of the working medium and reducing its molecular weight.

Limits of Chemical Engines

In thermal engines utilizing the energy of chemical reactions, which include the presently widely encountered LRE and the solid-propellent rocket engine (SRE), the working medium is formed as a result of a reaction between fuel and oxidizer. The temperature of the working fuel is determined by the heat of the reaction, and its molecular weight is determined by the molecular weight of the reaction products. The chemical reactions shown in Table 1 represent the optimum ratio between molecular weight and temperature from the standpoint of obtaining the greatest exhaust velocity.

Chemical rocket engines have almost reached the limit of their optimum characteristics today. The most optimum reactions using oxygen as the oxidizer were achieved long ago: Oxygen-kerosene and hydrogen-kerosene engines have now been used in space technology for many years. A certain improvement in characteristics may be achieved by using fluorine-containing oxidizers. But because fluorine is chemically an extremely caustic substance, the relatively small payoff in specific thrust, which may justify use of this chemical element, would hardly justify the operational inconveniences.

The most radical direction of improving the characteristics of chemical engines is to use free radical recombination reactions. A free radical is an electrically neutral atom or a group of atoms with an unstable electron shell, obtained as a result of dissociation of molecular compounds. For example in the reaction $H_2O \rightarrow OH + H$, the hydroxyl residue and atomic hydrogen are radicals. The reaction of formation of a molecule of hydrogen, $H + H \rightarrow H_2$, has the greatest energy (the specific energy of this reaction corresponds to an exhaust velocity of about 30 km/sec).

However, in view of the high propensity of free radicals for merger into a stable molecule, their accumulation and storage are possible only at temperatures close to 0°K, at which the rates of chemical reactions decrease dramatically. But so-called tunnel reactions remain possible even at 0°K. Therefore free radicals cannot be stored in pure form. The suggestion has been made to freeze radicals in a neutral matrix (for example atomic hydrogen could be fitted in the crystalline lattice of solid hydrogen); in principle, the concentration of free radicals could not exceed 50 percent in this case.

Even a mixture of 10 percent atomic hydrogen and 90 percent molecular hydrogen can increase the exhaust velocity by about 5 km/sec at a temperature of just 1,200°K. In more than 20 years of work on this problem, concentrations of free radicals not exceeding tenths of a percent have been achieved. Nonetheless the advantages which free radicals may provide are stimulating further research.

Nuclear Thermal Engines

The most promising direction for improving the characteristics of thermal rocket engines is to use the energy of nuclear reactions. As was noted earlier, nuclear reactions would best be used in systems where energy sources are separate from the ejected mass. Nuclear fuel would serve in this case as a source of heat imparted to the working medium.

In the simplest nuclear rocket engine, as is true for the reactors of atomic power plants, the reactor core consists of heat-emitting elements--compounds of uranium or plutonium contained in a shell. As a result of nuclear decay of the fuel, they heat up. Liquid working medium is fed into the reactor core by pumps. In it, it picks up heat from the reactor core, it evaporates, its temperature rises, and its velocity through the jet nozzle increases.

The highest temperature of the working fluid is limited by the melting point of the heat-emitting elements, and considering the necessary temperature gradient (to permit heat transfer) and the chemical stability of the materials, this temperature must not exceed 2,000°K. Because working medium in chemical engines has a temperature of 3,000-3,500°K, the sole means of making the exhaust velocity of nuclear engines with a solid reactor core greater than the exhaust velocity of chemical engines is to reduce the molecular weight of the working medium. Hydrogen has the minimum molecular weight (2 gm/mole), and with it, an exhaust velocity of 8-9.5 km/sec can be achieved. This is the upper limit for nuclear thermal rocket engines with a solid core. Characteristics close to these values were obtained in the USA with a "Nerva" experimental nuclear engine.

To permit further growth in the temperature of the working fluid in nuclear engines, we would have to switch to reactors in which the fissionable material is in gas phase. However, a number of problems arise in development of these gas phase nuclear reactors. For a nuclear reaction to be self-sustaining, a mass of nuclear fuel not less than critical must participate in the reaction. Inasmuch as the density of nuclear fuel in gas phase is low at high temperature, high pressures and large reactor cores must be used.*

The second difficult problem in developing gas phase reactors is the ejection of unreacted nuclear fuel together with working medium, which severely reduced the energy characteristics of the rocket.

We distinguish between homogeneous and heterogeneous engines depending on whether the working medium mixes with the nuclear fuel or the two are separated. The main shortcoming of homogeneous designs, one which places their suitability in doubt, is the great amount of uranium ejected together with working medium--about 100 kg per ton of working medium.

In heterogeneous systems ejection of nuclear fuel may be significantly decreased or even reduced to nought. An intense magnetic field that increases toward its margins is created with solenoids in the reactor space. The configuration of the field is such that what we call a magnetic "bottle" forms. This magnetic "bottle" has the property that a substance in plasma state may be contained within it for a sufficiently long time without presence of any solid walls.

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*Intermediate solutions would be possible where the bulk of the uranium is in solid state and only a small part of it is in gas phase. But then it would be difficult to achieve a high temperature for the working medium because the greater part of the energy would be liberated at relatively low temperature.

As a result of nuclear reactions uranium goes into a plasma state, and the magnetic field contains it, preventing it from mixing with the working medium (hydrogen). The latter flows about the magnetic "bottle" together with nuclear fuel, picking heat up from it. In order that mixing would not occur, laminar flow conditions must be observed. In this case effective heat exchange between the core and the working medium would be possible only by radiation. Because hydrogen is transparent to emissions from uranium plasma, 1-2 percent lithium must be added. Ionizing, the latter absorbs radiation intensively. It is anticipated that this system will produce an exhaust velocity of 20-30 km/sec with less than 2 percent of the uranium ejected, relative to consumption of the working medium.

Research is also being conducted on gas phase engines in which ejection of fissionable material does not occur at all. A diagram of the heat-emitting element of such an engine is shown in Figure 4. The engine is a capsule with double walls made from a transparent high-melting material (for example leucosapphire). The fissionable material, which is in gas phase under working conditions, is placed inside the capsule. The walls are cooled by pumping hydrogen between them. Inasmuch as both the walls and hydrogen are transparent to radiation, nuclear energy emitted in the form of radiation travels to the outside, where it heats up the hydrogen to which lithium had been added. The reactor core is assembled out of such heat-emitting elements.

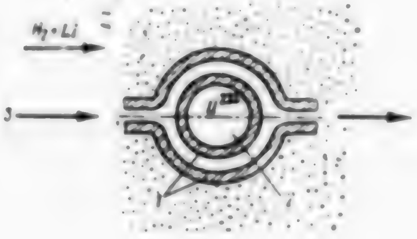

Figure 4. Core Cell of a Heterogeneous Gas Nuclear Rocket Engine: *1*--Sapphire walls, *2*--uranium plasma, *3*--working medium.

Implementation of this scheme is being retarded by the absence of suitable materials for the transparent walls, ones which would remain stable in contact with gaseous uranium at high temperature and in the presence of high radiation fluxes.

If a plasma can be contained in a magnetic "bottle," design of a thermonuclear engine utilizing a nuclear fusion reaction would be possible. However, impulse designs, which will be examined a little later on, are believed to be more promising in the use of thermonuclear fusion.

Electric Jet Engines

An electric jet engine is a device that converts electric energy produced aboard the rocket into the kinetic energy of ejected mass. The simplest method of conversion is utilized in so-called electrothermal engines, in which the working medium is heated by an electric current and then accelerated in a jet nozzle as in conventional thermal engines.

Although very high temperatures may be achieved with electric heating, engines in which the working medium is accelerated electromagnetically are more preferable. In such engines the energy of an electromagnetic field is converted into kinetic energy, and consequently there are no thermodynamic restrictions on the exhaust velocity and on the efficiency of energy conversion.

We distinguish among ion, plasma and high frequency engines in reference to the electomagnetic forces which are used to accelerate the working medium. In ion engines, acceleration occurs due to interaction of an electric field with ions or with charged macroparticles of the working medium. In plasma engines, interaction between a current and a magnetic field is employed. And finally, acceleration is achieved in a high frequency engine by the field of a traveling electromagnetic wave. In electric engines it is relatively simple to attain exhaust velocities of whatever magnitude desired, going as far as velocities close to the speed of light (for example if we use elementary particle accelerators as the engine).

Because of the absence of light accumulators of electric energy (storage batteries), utilization of the principle of electromagnetic acceleration makes sense only in combination with transformation of nuclear energy to electric energy. Presently there are no known direct methods of this transformation of any effectiveness whatsoever, and therefore use of self-contained electric engines is always examined in conjunction with an onboard atomic power plant with a thermal operating cycle.

The basic system of a space power plant includes, as is true with any terrestrial power plant, a heat source (a nuclear reactor in this case), a thermal machine (converting supplied heat into electric energy) and a cooler (a device drawing off spent heat). The most significant difference of space power plants from their terrestrial analogues is the method of heat removal. In outer space, heat can be discharged only by radiation.

How serious this fact is may be deduced from the following example. Emission of the heat of 1 kw at the average temperature of heat disposal in terrestrial power plants, 50°C, requires a cooler with a radiant surface area of 1.64 m^2. For an electric engine with a capacity of 100 kw, which corresponds to the power of an LRE with a thrust of only about 30 kg, and a total propulsion system efficiency of 20 percent, a cooler with an area of 1,300 m^2 would be required at the same temperature.

Energy emitted by a unit of surface area is proportional to the fourth power of temperature, and therefore to reduce the surface area of the cooler we would have to raise its temperature. Inasmuch as the efficiency of a power plant operating as a thermal machine is proportional to the difference between the temperatures of the heat source and the cooler, if we are to keep the efficiency constant we would have to correspondingly increase the temperature of the source.

Thus the overall task of raising the effectiveness of both thermal and electric engines is to create a high temperature reactor. The demands of space power engineering evoked intense research on high temperature direct conversion of heat into electricity.

The most promising conversion systems for space propulsion units have been found to be thermoelectronic converters (TECs). The principle of operation of a TEC is illustrated in Figure 5, where the TEC is a diode in which the interelectrode gap is filled with cesium vapor. At high temperature the cathode emits electrons which condense on the anode, charging it to a negative potential relative to the cathode. As a result a potential difference arises between the cathode and anode, and when they are connected to a load, an electric current flows through the circuit.

Cooling of the cathode elicited by "evaporation" of electrons and losses due to emission are compensated by heat input from a nuclear reactor. Heat emitted at the anode as a result of condensation of electrons and radiant heating by the cathode is drawn off by a heat carrier or by direct radiation into outer space.

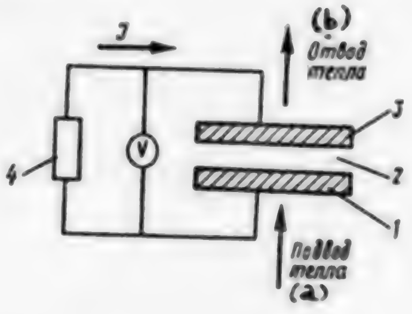

Figure 5. Basic Diagram of a Thermoemissive Converter of Thermal Energy Into Electric Energy: *1*--Cathode, *2*--interelectrode gap filled with cesium vapor, *3*--anode, *4*--load.

Key:

a. Heat input

b. Heat withdrawal

A thermoelectronic converter with a tungsten cathode can operate at cathode temperatures up to 2,500°K and anode temperatures up to 1,000-1,400°K, given a relative power output from 5 to 40 w/cm^2 at an efficiency of up to 25 percent. One shortage of TECs is their low operating voltage (about 0.5 v), and therefore elements are connected in series.

Theoretically the temperature of heat disposal that is optimum from the standpoint of cooler dimensions must be 75 percent of the temperature of the heat source. Given the temperature restrictions imposed on a solid core reactor, the cooler-emitter will always be the most cumbersome part of the space power plant, if not the heaviest. If the cooler is to work effectively its surface must have a temperature close to the low temperature of the heat cycle.

This cannot be achieved by capitalizing on natural thermal conductivity of materials; what we need is forced transfer of heat, achieved by circulating a liquid or gas heat carrier. In this case we suffer initial losses of energy in pumping the heat carrier; moreover the power plant becomes extremely vulnerable to puncture by meteorites. When the surface area of the cooler is large, the probability that it would be struck by a meteorite with dimensions sufficient to rupture the wall of a heat carrier channel rises sharply, and the power plant would undergo depressurization and break down.

The best design solution permiting us to avoid these problems (power loss and meteorite puncture) is to use heat pipes. A heat pipe is a channel containing circulating heat carrier with a so-called core (a fine-mesh network in the simplest case) lining the inside wall and separated from it by a gap. At first the evacuated pipe is filled with a quantity of liquid sufficient to fill the gap between the core and the wall of the pipe, where it remains trapped by capillary forces.

Heating, heat transfer and cooling zones are distinguished in a heat pipe. In the cooler-emitter the last two zones are combined as a rule. Heat fed into the heating zone evaporates the liquid, the vapors of which pass through an opening in the core into the inner space of the pipe and then flow into the cooling zone. There the liquid undergoes condensation, transferring its heat of condensation to the walls of the pipe, from which it is drawn off by emission. Liquid formed as a result of condensation is returned to the heating zone by capillary forces created in the core and in the gap between the core and pipe wall.

This heat transfer process is so effective that, for example, pipes that have been tested thus far can transmit a heat flux of 10 kw for every square centimeter of pipe cross section for a distance of several meters, given a temperature gradient of not less than 0.01°K between the ends of the pipe. This is equivalent to the heat transfer of a solid rod with a thermal conductivity factor exceeding by several thousand times the corresponding value for copper. Only systems with liquid metal heat carriers can compete with heat pipes in terms of their possibilities for transporting heat, but these require expenditure of work to pump the heat carrier.

The surface of the cooler-emitter is composed of heat pipes. The heat input zone may either be directly in contact with the cooling unit or bathed by an intermediate heat carrier. Inasmuch as many heat pipes must be used to create the emitting surface and the pipe channels need not be interconnected, damage to one or several pipes by a meteorite would only have an insignificant effect upon the work of the entire unit.

Heat disposal systems are possible where the heat carrier is represented by ferromagnetic dust (Figure 6), which is pumped through a heat exchanger, where the waste heat of the power plant is removed. Then the ferromagnetic particles are dumped outside the unit. There they are recaptured and returned to the pump intake. In a magnetic field the ferromagnetic particles link together into flux lines, creating a radiant shell. If the permeability of the dust is sufficient, the entire external magnetic field remains concentrated in this shell, and it does not undergo useless scattering.

The advantages of this type of cooler-emitter are its complete invulnerability to damage by meteorites and its small dimensions, assuming that the power plant is carried away from the surface of the earth to satellite orbit, since in this case the dust may be held by a small container. This system is presently still in the theoretical development stage. Its implementation is being hindered by the absence of light and economical sources of a magnetic field.

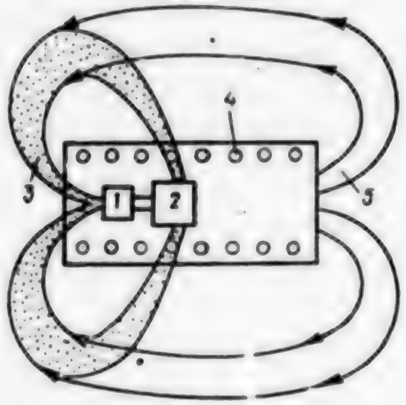

Figure 6. Diagram of a Dust Cooler-Emitter: *1*--Pump, *2*--heat exchanger, *3*--ferromagnetic dust, *4*--solenoid winding, *5*--magnetic field flux lines.

Impulse Engines Using Microexplosions and the Photon Engine

The principle of operation of impulse nuclear rocket engines (INREs), diagrams of which are shown in figures 7*a* and *b*, involves production of periodic nuclear or thermonuclear explosions above the surface of a massive reflector. The essential elements of an INRE are a source of a magnetic field which would prevent striking of the reflector surface by charged reaction products and a shock absorber which would smooth out the impulse load transmitted to the rocket.

Usually in such engines explosions cause evaporation of either the reflector material or a working medium fed to the surface of the reflector. Moreover to improve the conditions under which the nuclear reaction proceeds, to increase the proportion of reacted atoms and to reduce the temperature of the explosion, the nuclear charge is contained in a rather thick jacket made of some inert material. As a result the ejected mass would consist mainly of substances not taking part in the reaction (hydrogen, lithium etc.), and the exhaust velocity of such engines would be limited to 100 km/sec.

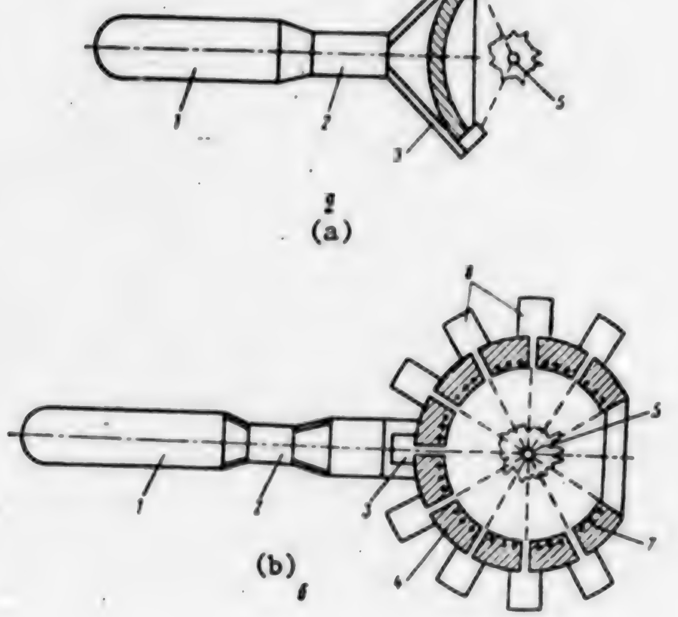

Figure 7. Diagrams of Impulse Engines (*a*--using transuranium elements, *b*--thermonuclear engine): *1*--Spacecraft, *2*--shock absorber, *3*--nuclear fuel feed system, *4*--reflector, *5*--explosion zone, *6*--energy conversion system, *7*--winding to create magnetic field, *8*--reaction ignition system (charged particle accelerators or lasers).

If satisfactory technical concepts for cooling the reflector without causing evaporation of its material are found and if it becomes possible to effect a nuclear reaction without the need of a jacket to surround the charge, the exhaust velocities of such engines may approach the theoretically possible values--10^5 km/sec. In this case INREs would have a lower specific weight than electric engines, since the proportion of removed heat would be significantly lower (for electric engines it is 75-90 percent of the power of a nuclear propulsion unit), and heat exchange could be performed at a higher temperature. As a result the area and correspondingly the weight of the cooler-emitter would be significantly lower.

The main problem with nuclear fission reactions is to reduce the mass of the nuclear fuel necessary for a self-sustaining nuclear reaction (the critical mass). The critical mass of nuclear fuel in wide use today, consisting of uranium-235 and plutonium, is so great (for example 1 and 3 kg) that direct use of these elements in an INRE is precluded by the excessively great energy released by explosion of such a mass.

The critical mass can be reduced significantly by increasing the density of the dividing substance by compressing it at a pressure of 10^{14}-10^{15} Pa or by switching to chemical elements with greater nuclear mass--the transuranium elements. Modern technology permits creation of impulse pressures of the required magnitude, but this would be possible only with complex and heavy devices which would be more suited to fusion reactions. Therefore only the transuranium elements (primarily californium-252) can be used as fuel in fission INREs.

The critical mass of californium is about 7 gm, and when such a mass explodes, 10^{10} j are released. A diagram of an engine using californium is shown in Figure *7a*. In it, special accelerators located on the periphery of the reflector shoot out particles of californium. Colliding simultaneously, they generate a critical mass that initiates the nuclear explosion. Moreover the critical mass may be reduced by 1.5-2 times by capitalizing on compression arising upon collision of the particles. The explosions are repeated until such time that the rocket reaches the needed velocity: Several kilograms of californium would be needed to accelerate a rocket with a sustained-flight mass of 100 tons to a velocity of 10 km/sec.

However, given their fundamental simplicity, engines using transuranium elements possess a number of significant shortcomings, and there is little chance that they could be realized in the near future. Californium is very expensive, it does not occur naturally, and it must be obtained by irradiating heavy elements in proton accelerators or by high-power neutron fluxes. In this case the useful yield of californium is very low; for example production of californium in the USA in the 1960s was a total of only 1 gm per year. Inasmuch as the half-life of californium-252 is 2.5 years, at this production level it would be generally impossible to accumulate a critical mass.

And finally, even if the needed quantity of californium is obtained, it could be stored in a rocket only in the form of small particles separated by a large quantity of neutron absorber, which would increase the weight of the engine. Moreover transuranium elements explode to form heavy fission fragments that are hard to contain by the reflector's magnetic field, and a large number of neutrons that practically do not interact with the magnetic field. As a result, keeping the engine structure cool becomes a difficult problem.

The reserve of californium required could be reduced somewhat by feeding uranium into the explosion zone every 10^{-6}-10^{-5} sec, in about the same quantities as californium. In this case the uranium would burn in the neutron flux created by the explosion of californium. Then after the same time interval the next batch of uranium could be fed in. Thus a cascade reaction would result, but it would be an attenuating reaction, and after three to five cycles more californium would have to be exploded.

A more promising approach would be to use californium to initiate a thermonuclear reaction. In this case californium would be used only once, and then batches of thermonuclear fuel (for example a deuterium-tritium mixture) would be fed into the reaction zone continuously. Thermonuclear fuel is incomparably cheaper than californium, and economic factors would not play such a significant role in the development of this kind of engine. Moreover a thermonuclear reaction produces light elements, making it much easier to provide thermal protection to the reflector.

However, even if we ignore the problem of how to feed the thermonuclear fuel into the combustion zone, the minimum level of continuous power required for this self-sustaining reaction would be 10^{14} w. This is more than 1,000 times the power of the engines of a Saturn-5 rocket. At an exhaust velocity of 10^{3} km/sec, such an engine would have a thrust of 10,000 tons. And consequently the problem of heat removal becomes extremely difficult at the required power level. If we assume that just 0.1 percent of the energy is released in the structural elements of the engine, removal of this quantity would require a cooler-emitter with a surface area of 10,000 m^2.

If a heat removal system using a working medium is introduced, the exhaust velocity would decrease to a third, and correspondingly the thrust would increase to 30,000 tons. Creation of such thrust would require a working medium consumption rate of 1,000 kg/sec. A rocket weighing 10,000 tons equipped with such an engine could achieve a velocity of 100 km/sec in a little more than an hour.

The engine designs employing thermonuclear microexplosions are closer to reality. These engines were discussed rather extensively in print, and several conceptual drawings of these engines were published. The essence of thermonuclear microexplosions lies in so-called inertial plasma containment, where the reaction manages to occur before heated thermonuclear fuel is able to disperse in response to the high temperatures needed to initiate the thermonuclear reaction.

In the design of a fixed thermonuclear reactor mentioned earlier, the main and still-unsolved problem is that of containing hot plasma by a magnetic field. To achieve a controlled thermonuclear reaction at a temperature of several million degrees, we would have to satisfy Lawson's criterion, $n_{\tau} \geqslant 10^{14}$, where n is the particle concentration (the number of atoms per cubic centimeter) and τ is time. With inertial containment, Lawson's criterion is satisfied owing to a sharp rise in concentration; as a result the time necessary for the thermonucleat reaction to proceed decreases by the same amount.

This is achieved by symmetrical pulsed irradiation of a small target of nuclear fuel using the emissions of a high-power laser or a high-intensity flux of charged particles (electrons and ions). Moreover the energy flux must grow sharply during the pulse. Irradiation causes intensive evaporation of the surface layer of the target--so-called ablation. The evaporating particles acquire considerable velocity, and similarly as with jet engines, they create a recoil impulse that causes development of enormous pressure attaining many billions of pascals.

The ablation effect is multiply intensified by the convergent shock wave, as a result of which the fuel density in the target center grows by several thousand orders of magnitude, and pressure attains a value corresponding to that in the center of stars (about 10^{16} Pa). In this case the thermonuclear fuel undergoes heating, and conditions permitting a thermonuclear reaction arise.

Targets with a mass of just 0.001-0.01 gm are enough to effect a microexplosion. This mass corresponds to a microexplosion energy of 10^{8}-10^{10} j. However, 80 percent of the target material is carried away by ablation and does not participate in the reaction; moreover the energy yield of the reaction would hardly exceed 30 percent. As a result the maximum exhaust velocity for thermonuclear microexplosions would be about $6 \cdot 10^6$ m/sec, which corresponds to a specific thrust of $6 \cdot 10^5$ sec. For explosions initiated by electron beams, the target must be surrounded by a jacket made of elements having high atomic weight, which would reduce the maximum exhaust velocity even more.

A diagram of an engine using thermonuclear microexplosions is shown in Figure 7*b*. What makes these engines fundamentally different from engines using transuranium elements is the presence of a thermonuclear reaction initiating system and an electric power source for it. The initiating system is either a set of light radiation sources or charged particle accelerators arranged in such a way that they could irradiate the target as symmetrically as possible. One high-power laser can be used as the radiation source if its beam is divided into several smaller beams, or a combination of lasers may be used.

The target is shot into the space over the reflector, and at the moment it passes through the focal point of the beams an igniting impulse is created. The thermonuclear plasma is reflected off of a magnetic field generated by superconducting solenoids and ejected outward, creating a jet thrust. Either special solenoids or the same solenoids used as sources of the protective magnetic field can be used to produce electric power. When the moving plasma interacts with the magnetic field an electromotive force is created in the solenoids, and the produced electric energy is used to generate the next impulse.

The American plan for a thermonuclear engine using laser reaction initiation calls for a laser with a pulse energy of 1 Mj, a pulse duration of 10 nsec and a pulse repetition frequency of 500 Hz. The weight of the laser is estimated at 150 tons. Given an energy of 10^8 j released by a single microexplosion, in the estimate of the plan's authors such an engine could accelerate a 100 ton payload to a characteristic velocity of 10 km/sec within 1 day. This would require about 10^8 microexplosions.

English scientists propose initiating the thermal reaction by electron accelerators in their plan for a thermonuclear microexplosion engine. The repetition frequency of the "igniting" pulses is 100 Hz, and the energy released by each microexplosion is 10^{11} j. Several hundred tons of thermonuclear fuel would be burned in the course of a year to accelerate a 100 ton payload to fifteen one-hundredths of the speed of light.

The main difficulty in creating impulse thermonuclear engines is developing the reaction initiating system. It is precisely the absence of the appropriate lasers and accelerating devices that has made a controlled thermonuclear reaction impossible as yet. The mass of the initiating system is proportional to the energy of the microexplosion, therefore it would be desirable to have the lowest possible energy release with every explosion. But then a high pulse repetition frequency would be required to maintain the prescribed thrust, and to achieve the prescribed characteristic velocity, a correspondingly larger quantity would be required. But the permissible number of impulses is limited by the system's life.

In this case the Soviet scientists Ye. P. Velikhov and V. V. Chernukha proposed a method of cascade ignition of thermonuclear targets. What their method essentially entails is that about 10^{-6} sec after the first target is ignited a more-massive target is fed into the explosion zone, and part of the energy of the first explosion is used to initiate the next reaction. Then a target of even greater mass is fed in, and so on. Using targets which release 10 times more energy in each cascade, we can achieve an explosion energy of 10^{10}-10^{11} j using an initiating system releasing an energy of 10^{8} j.

In this case the pulse repetition frequency would decrease correspondingly, but at the same time the impulse load upon the reflector would naturally increase. In a cascade system, a possibility arises for using fuel that is harder to ignite in subsequent steps of the cascade (pure deuterium for example). This sharply reduces the need for tritium and simultaneously decreases the neutron yield.

Another no less important task associated with developing impulse thermonuclear engines is the removal of heat released within the structure. As was indicated earlier, in a deuterium-tritium reaction up to 80 percent of the energy is carried away by neutrons that are not contained by the reflector's magnetic field. A fundamental solution to this problem would be to use a mixture of ordinary hydrogen and boron-11 isotope as the thermonuclear fuel. Although the energy released upon combustion of this fuel is lower than with a deuterium-tritium mixture, neutrons are totally absent. However, this reaction requires a higher temperature for its initiation, and its achievement is a matter of the remote future.

According to the basic postulate of the theory of relativity the maximum possible velocity in nature is the speed of light--300,000 km/sec. Naturally this would also be the maximum for the exhaust velocity of rocket engines. Velocities attaining the speed of light may be achieved in electric engines, for example in electron or ion accelerators. However, as follows from the general principles of physics, in this case the energy expended to accelerate particles would be used more suitably, from the point of view of achieving a maximum characteristic velocity, to create thrust through electromagnetic radiation.

We know that electromagnetic radiation, which includes visible light, exerts a pressure on material bodies. Correspondingly a radiating body experiences a recoil pulse from photons of the electromagnetic field. Therefore every directionally emitting body can be a photon engine. The jet thrust created by directed radiation is equal to the emission power divided by the speed of light--that is, every kilowatt of emitted power creates a thrust of $3.3 \cdot 10^{-7}$ kg.

The simplest photon engine would be one that is shielded on one side by a cooler-emitter. Inasmuch as about 10 percent of the energy generated by the onboard power plant winds up in the energy of the jet of the electrojet engine, at an exhaust velocity equal to one-tenth of the speed of light the thrust generated by the cooler-emitter would be comparable to the thrust of the engine.

Despite the relative simplicity of photon engines, they are not suited to any of the energy sources used today, including thermonuclear. Usually, only part of the mass of the source is converted into energy: 0.5 percent for nuclear fission reactions and 0.15 percent for thermonuclear reactions. If we use only photons as the working medium the reaction products would have to be accelerated to the final velocity simultanecusly with the payload. Therefore it would make sense to use photon engines only in combination with energy sources in which the entire mass, or at least the greater part of it, is converted into energy. According to present ideas only the annihilation reaction--that is, interaction of particles and antiparticles--can serve as such a source.

Synthesis of antiparticles (for example antiprotons) requires powerful accelerators. Even so, the yield of antiparticles in the reaction is very low. It is believed that acquisition of 1 j of energy locked in antiprotons would require consumption of electric energy totaling not less than 100 kj. Thus accumulation of any significant quantity of antimatter is now beyond the possibilities of modern technology.

Another problem arising in realization of photon engines is storage of the antimatter. Inasmuch as the material of which the rocket is made is ordinary matter, all contact of the antimatter with the walls of the tanks must be precluded. Therefore the antimatter must be "suspended" in electric or magnetic fields.

The requirements imposed on the heat removal system of photon engines will be extremely stiff. The heat removal systems presently achieveable, including the cooler-emitter, have a mass of not less than 0.01 kg per kilowatt of waste power. In this case even if we ignore the other components of the rocket, it would have an acceleration of not more than $2 \cdot 10^{-4}$ m/sec^2, and it would take more than a year to accelerate such a rocket to a velocity of just 10 km/sec.

It follows from all of the above that creation of a photon engine is a matter of the highly remote future. A number of researchers are casting doubt upon the sensibility and even the fundamental possibility of its creation, while others treat the photon engine as science fiction.

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RECURRENT-ITERATION ALGORITHM FOR SOLVING CHARACTERISTIC EQUATION OF STABILIZED SPACE VEHICLES

Moscow KOSMICHESKIYE ISSLEDOVANIYA in Russian Vol 20, No 4, Jul-Aug 82
(manuscript received 12 May 81) pp 505-520

RABINOVICH, B. I., LEBEDEV, V. G., KALININA, A. V. and NARKUNSKAYA, G. S.

[Abstract] The authors describe a recurrent-iteration algorithm for solving the characteristic equation of a system of linearized equations of perturbed motion. It is assumed that the stabilization system is described either by some system of linear differential equations or by a set of transfer functions or frequency characteristics corresponding to different observed coordinates. The RI algorithm described here by the authors is based on the representation of some meromorphic function transformable in the course of the recurrent process in the form of the sum of simple fractions and application of an iteration procedure for finding its zeroes in each interval of this process. The initial variant of this algorithm was described in an earlier article. It has now been modified, having a considerably more general character which makes it possible to examine extremely complex systems, successively refining or changing the mathematical model of the regulated object and its parameters and form, and the parameters of the control law (stabilization algorithm) in the course of synthesis of the latter. This makes possible an effective investigation of the stability and mechanism of appearance of dynamic instability in systems with many degrees of freedom (liquid fuel in tanks and lines, elastic housing, elastic antennas, solar cells, etc.). Approximate expressions for the roots of the characteristic equation of the closed system through the roots of the characteristic equation of the regulated object, lying at the basis of a number of investigations of the dynamics of spaceships and carrier-rockets, are derived in an RI algorithm as initial approximations. Figures 5; references: 16 Russian.
[2-5303]

UDC 62.50

INTEGRATION OF EQUATION OF MOTION FOR FREE GYROSTAT

Moscow KOSMICHESKIYE ISSLEDOVANIYA in Russian Vol 20, No 4, Jul-Aug 82
(manuscript received 22 Jan 81) pp 521-528

ZLOCHEVSKIY, S. I.

[Abstract] A study was made of the motion of a free gyrostat relative to its center of mass. The gyrostat consists of a supporting solid body on which three axially symmetric flywheels are mounted. It is assumed that the axis of rotation of each flywheel coincides with its axis of dynamic symmetry and the center of mass of the flywheel is situated on the axis of rotation. The axes of rotation of the flywheels are parallel to the principal central axes of inertia of the gyrostat; these are used as the axes of a coupled coordinate system $OR_1R_2R_3$. A reference coordinate system $OX_1X_2X_3$ is coupled to the center of mass of the gyrostat. The principal central moments of inertia of the gyrostat are denoted I_1, I_2, I_3 and the components of the instantaneous angular velocity of the supporting body on the coupled axes are denoted p_1, p_2, p_3. Euler-Krylov angles δ_1, δ_2, δ_3 are introduced for determining the position of the gyrostat supporting body relative to the reference coordinate system $OX_1X_2X_3$. With transformation from the coordinate system $OX_1X_2X_3$ to the coupled system $OR_1R_2R_3$ the first rotation is by the angle δ_1 about the OX_1 axis, the second is by the angle δ_2 about the position of the OX_2 axis and the third by the angle δ_3 about the new position of the OX_3 axis. Viscous friction in the pivots of the flywheel axes is taken into account. The equations of motion of the gyrostat about a fixed point, the center of mass, jointly with the equations of motion of the flywheels, are integrated by the small parameter method. The Lyapunov majorizing functions method is used in evaluating the upper limit for the small parameter at which the series in powers of the small parameter absolutely converge to a solution. Finally, a qualitative analysis is made of the influence of viscous friction in the pivots of the flywheel axes on oscillations of the gyrostat. References 10: 9 Russian, 1 Western.
[2-5303]

UDC 629.78

MAXIMIZING ENTRY CORRIDOR AND MINIMIZING ENERGY EXPENDITURES WHEN PUTTING SPACE VEHICLE INTO JOVIAN ARTIFICIAL SATELLITE ORBIT BY COMBINED METHOD

Moscow KOSMICHESKIYE ISSLEDOVANIYA in Russian Vol 20, No 4, Jul-Aug 82
(manuscript received 24 Mar 81) pp 529-541

IVANOV, N. M., MARTYNOV, A. I. and SOKOLOV, N. L.

[Abstract] A study was made of some of the control problems involved in putting a space vehicle of the glancing type into the orbit of an artificial

Jovian satellite when making use of preliminary aerodynamic braking in the atmosphere and additional atmospheric correction of vehicle motion. With this formulation, the authors present solutions of the variational problems involved in seeking for the maximum width of the entry corridor and the minimum of the required expenditures of energy in forming an orbit. This is followed by consideration of some quasi-optimum programs for control in the atmospheric segment of motion. This is illustrated by numerical data and graphs. It is shown that atmospheric correction is highly effective when using the proposed combined method for putting a Jovian artificial satellite into orbit. It is further demonstrated that by this method it is possible to broaden the entry corridor by an average up to 20% by an increase in the total power expenditures by not more than 10-13%. There is a decrease in the total energy expenditures for space vehicles with stipulated characteristics and with a stipulated entry corridor by a factor of 2-3. The firing of the engine is possible and desirable only with entry near the lower boundary of the corridor with use of simplified control programs. A determination of the necessary range of the entry corridor where it is necessary to fire the engine is determined unambiguously on the basis of the time when some fixed apparent velocity is attained. Figures 6; tables 3; references: 5 Russian.
[2-5303]

UDC 523.035:523.42

LABORATORY CALIBRATION OF 'FOTON-1' SPECTROMETER INTENDED FOR MEASURING ATMOSPHERIC GLOW IN ULTRAVIOLET WAVELENGTH RANGE ON 'IKB-1300' SATELLITE

Moscow KOSMICHESKIYE ISSLEDOVANIYA in Russian Vol 20, No 4, Jul-Aug 82 (manuscript received 23 Mar 82) pp 620-630

KOZLOVSKIY, M. Yu., KURT, V. G., NUSINOV, M. D., PEREVODCHIKOVA, T. V., POGODIN, Yu. S., SMIRNOVA, L. P., GOGOSHEV, M. and SARGOYCHEV, S.

[Abstract] The authors give a detailed description of the method for laboratory calibration of the "Foton-1" UV spectrometer carried aboard the "Intercosmos-Bolgariya-1300" satellite for measuring the resonance glow of the upper atmosphere in the range 1150-2500 A. Among the technical specifications of the instrument are the following: spectral resolution — 20 A; field of view — 11.5° x 11.5°; geometry factor — $1.5 \cdot 10^{-3}$ $cm^2 \cdot sr$; line dispersion — 20 A/mm; number of grating rulings — 1200 mm^{-1}; radius of curvature — 224.2 mm; dimensions of ruled surface — 37 x 42 mm; direction of measurements — nadir; area of observation at altitude 100 km — $2 \cdot 10^4$ km. It is difficult to calibrate instruments in the short-wave UV range because the radiation source, optical measuring system and the instrument to be calibrated itself must be placed in a high-vacuum chamber and this makes system adjustment difficult. When using vacuum technology special measures must be taken to prevent contamination of the optical reflecting surfaces by vapors of oils from the vacuum pumps. These and other problems were

solved in the described calibration complex. Figure 1 in the text is an electrical and optical diagram of the calibration apparatus with 13 components identified. The operating principle is fully described with reference to this figure. The calibration is accomplished using a scanning vacuum monochromator in which the secondary standard is a hydrogen source and the input flux of UV radiation is measured using a standard photomultiplier calibrated with synchronous radiation. Contamination of the optical reflecting surfaces was totally eliminated by use of the innovative vacuum apparatus. The true response of the "Foton-1" was determined, as well as its dynamic range. Analysis of the daytime and nighttime spectra of radiation of the earth's atmosphere revealed entirely satisfactory performance of the "Foton-1" during a flight experiment. Figures 5; tables 1; references 24: 6 Russian, 18 Western.
[2-5303]

COMMENTARY ON ECONOMIC BENEFITS FROM SPACE PROGRAM

Moscow EKONOMICHESKAYA GAZETA in Russian No 39, Sep 82 p 21

[Article by I. Isachenko, candidate of economic science: "Space and Economics"]

[Text] The 125th anniversary of the birth of the founder of modern astronautics, K. E. Tsiolovskiy, which was recently widely celebrated in the USSR, coincided with a number of events pointing to the new, outstanding achievements of Soviet science and technology in space exploration. The program of investigations and experiments on board the Salyut-7--Soyuz scientific research complex was completed successfully and its crew of five for the first time included a female astronaut. The main complement of the Salyut-7 crew is continuing work in orbit for the fifth month. The scientific data obtained by them will be used in the interests of various branches of science and the national economy, as well as for further development of manned space flights.

There was a time when people asked the question: What is the practical value of space exploration? Now, the question does not arise. Astronomy, weather service, medicine, biology, agriculture, metallurgy and many other spheres of application need the data that can only be obtained in space orbits. The outlays for space are beginning to be repaid with interest.

The current level of outlays throughout the world on space exploration and development is estimated in billions of dollars annually.

The development and practical use of new hardware for economic purposes is a major result of the activity on space exploration and development.

Space Communications

Communication via satellites has become an integral part of the infrastructure of the modern world economy. UN experts estimate that 95 satellite communication systems are operating in the world or planned for operation by 1985. Of these, three are international, five are regional and 70 are national systems based on owned communication satellites or leased communication channels on the satellites of other countries and international organizations. Despite the continuing development as well of other, non-space, types of communication, the volume of information transmitted via satellites is growing steadily. Forecasts predict that by the year 2000, satellite communication systems will be carrying up to 25 percent of all long-distance radiotelephone communications and up to 50 percent of video and digital information transmissions.

Putting satellite communication systems into operation has expanded considerably the qualitative capabilities of serving consumers. Satellites have made it possible to create the first global communication system, which was a major step in the evolution of information technology, and they have allowed direct transmission of television from the sites of international events to all countries in the world. The communication lines of the INTELSAT international satellite system now serve more than 140 countries in the world. Soviet communication satellites, the technical basis of the Intersputnik international system, are used for regular exchange of television programs and support of telephone and telegraph communication with many countries in Europe, Asia, Africa and America.

The substantial economic benefits from organizing long-distance telephone communication and television broadcasting have been demonstrated by regional and national satellite communication systems. Putting the Molniya-Orbita into operation in the USSR, the world's first national space communication system, and its further development combined with ground facilities have allowed organizing television broadcasting throughout the entire country. Soviet and foreign experience shows that the reduction in cost when television programs are sent via satellites compared to that of the technology previously used can reach 60-65 percent. Only when the Indonesian Palapa national satellite system was placed into operation did it become possible to cover the territory of this country, including more than 5,000 islands, with communication facilities.

Solving the problems of direct broadcasting via satellites to small collective and individual receivers will enable implementation of the extensive use of television for education. Also under active consideration are some other capabilities of communication satellites that promise many economic benefits.

Serving sea navigation has now become a major direction in the use of space technology. The reliability and speed of satellite communications are its decisive advantages which conventional shortwave radio communication in use lacks. They produce a considerable reduction in operating expenses. Using satellites allows organizing reliable supply to ships of current weather information and an effective storm warning system, selecting the most advantageous and safest routes, and produces a considerable savings in passage time. All this is improving substantially the conditions of operating the shipping, passenger and fishing fleets and promoting an increase in the profitability of sea navigation.

By the end of 1981, about 900 ships had been equipped with satellite communication stations. INMARSAT experts believe that such stations will have been installed on another 1,700 ships by the end of 1987. Since the beginning of 1982, the system of space facilities of the International Organization of Maritime Satellite Communication, INMARSAT, embracing 37 of the world's major sea powers, has been providing service to ships in the Atlantic, Pacific and Indian Oceans.

Sea navigation practice still indicates that the inadequate precision of navigational fixes in a number of cases leads to considerable damage and loss of life since the low efficiency of communications in use hinders organization of search and rescue operations. Thus, just in the period of 1978-1980, more than 750 major ships sank due to various causes. A substantial enhancement in the effectiveness of finding ships and aircraft suffering misfortune on the seas will be provided by the international space system, KOSPAS-SARSAT, developed jointly by specialists from the USSR, United States, France and Canada. The equipment developed under the joint project allows determining the location of ships and aircraft in need of help to within 3 to 5 kilometers.

Weather Reconnaissance and Mineral Prospecting

Improvement in methods of weather prediction and enhancement of forecast accuracy are afforded by the space technology of observing development of atmospheric processes. A world system of space weather observations was developed by the efforts of the USSR, United States, Western Europe and Japan; the information derived from it is used extensively in compiling local and global weather forecasts.

The actual national economic value of reliable weather forecasts determines the economic effectiveness of using weather satellites. Thus, the Meteor space system, which has been operating successfully in the USSR for over 15 years now, annually yields a savings of 500 to 700 million rubles for the national economy. The Americans estimate that the information derived from weather satellites yields an annual savings on the order of 172 million dollars for the U.S. economy; a study has shown in particular that compiling charts of the ice fields in the Great Lakes, which allow prolonging navigation, will save up to 35 million dollars per year; localization of a cold water outlet to the ocean where tuna and salmon gather, which enables increasing catches and saving fishing vessel running time, saves 2.44 million dollars.

A considerable national economic effect is provided by prospecting for earth's natural resources from space. Information derived from near-earth orbits is of great practical value in forecasting the harvest of agricultural crops, estimating pasturage and timber resources, analyzing land use, prospecting for geologic resources, determining catchment areas and identifying water pollution sources, and estimating damage from natural disasters. According to estimates, costs for space photography of the arth's surface per unit of area are 10-15-fold lower than that for aerial photography.

Space photography from the Meteor-Priroda Soviet orbiting stations and satellites is being applied practically in implementing the plans for efficient development of the fuel-raw materials base in the USSR in unity with the complex of measures for protecting nature which ensure efficient use of nature and reproduction of soil and water resources. Effectiveness in the application of space technology has been confirmed by the practice of planning, constructing and developing the territorial production complexes in Eastern Siberia, Kazakhstan and Central Asia.

A significant contribution to the development of various sectors of the economy is being made by the information derived from American and Indian satellites for investigating natural resources. U.S. specialists estimate that use of the continuously operating space complex for investigation of natural resources is capable of yielding an economic gain that exceeds its development and operating costs 4.3-9.3-fold. Overall annual economic effect in this case is estimated at 0.5-1.1 million dollars.

The space technology applications considered above for economic benefit do not exhaust all the potential capabilities of the positive effect of astronautics on the economy. Other promising projects are being developed.

Discussing the Militarization of Space

The second UN conference on the peaceful use of space was held recently in Vienna. Representatives of about a hundred countries gathered at this international forum to discuss the results of the first 25 years of the "space age," which began when a Soviet satellite was launched in October 1957.

At the last conference, the majority of its participants expressed serious concern about U.S. plans and specific measures aimed at militarization of space. Openly defying international law, the United States has set up an entire complex of military space systems for reconnaissance, communications and control, navigation and meteorological and topographical support. The next steps in militarization of space are defined in President Reagan's special directive on national policy for developing space in the forthcoming decade.

The Pentagon's space ambitions are placing a heavy burden on taxpayers: According to official American data, the growth rate for U.S. expenditures on the military space program in the last three years has exceeded 20 percent.

The U.S. adventurist policy conflicts with the consistent policy of the Soviet state with respect to using space exclusively for peaceful purposes and for further evolution of international cooperation in space exploration and development. This position was confirmed in L. I. Brezhnev's welcoming address to the conference:

"The Soviet Union consistently advocates space remaining an arena of peaceful cooperation and the vast expanses of space being free of any type of arms. Achieving this lofty and humane goal through joint efforts is not just really, but also vitally necessary in the name of the future of all mankind."

PHOTO CAPTION

1. p 21. The All-Union Institute of Agricultural Aerial-Photographic Geodesic Surveys has begun developing agricultural thematic charts for the various regions in the country by using aerospace observations. These charts are needed for development of scientifically sound agriculture.

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SPACE APPLICATIONS IN COMMUNICATIONS, METEOROLOGY, GEOLOGY

Moscow IZVESTIYA in Russian 4 Oct 82 p 2

> [Text] There is almost no branch of the national economy for which the conquest of space would not be useful. The decisions of the 26th CPSU Congress provide for the further study and conquest of space for the benefit of the development of science, technology and the national economy. Specialists who have gathered at IZVESTIYA's "round table" tell about some of the effects it is and will be having.

Communications

Moscow IZVESTIYA in Russian 4 Oct 82 p 2

[Article by V. Shamshin, USSR Minister of Communications: "Lightning-Fast Communication"]

[Text] One of the very first practical applications of cosmonautics was in the development of communications. The organization of communications over long distances with the help of communications satellites insures high quality, is economical and--the main thing--takes less time. For our country, with its vast spaces, this is of colossal importance. The "Orbita" space communications system, which at first used "Molniya" satellites, has been in operation in the Soviet Union since 1967. By the 50th anniversary of Soviet power, 20 ground stations had been built for this system. That caused an immediate increase of 20 million viewers of Central Television's First Program. And now, because of the supplementing of ground lines with "Molniya," "Raduga," "Ekran" and "Gorizont" communications satellites, Central Television's programs can be seen by about 90 percent of our country's populace. Those same communications satellites also provide Moscow with telephone and telegraph communications with dozens of the most remote cities in the country.

Along with further expansion and improvement of the network of ground stations of the "Orbita" type, a network of considerably simpler and cheaper stations of the "Ekran" and "Moskva" types, for the reception of Central Television programs, is being developed at accelerated rates. They can be placed in settlement communication departments and kolkhoz and sovkhoz offices. When combined with a television retransmitter, such an installation services a circle with a radius of several dozen kilometers.

Photocopies of central newspapers are transmitted to Khabarovsk, Irkutsk and other cities over satellite communication channels, and this network is being enlarged continually.

The international "Intersputnik" system, which was created on the initiative of the socialist states and is based on the Soviet Union's communications satellites, is playing a large role in the organization of communications with other nations.

Meteorology

Moscow IZVESTIYA in Russian 4 Oct 82 p 2

[Article by Yu. Izrael', chairman, USSR State Committee for Hydrometeorology and Environmental Control: "Sky Patrol"]

[Text] The "Meteor" space system, which supplements ground observation data substantially and makes it possible to improve the accuracy of forecasts, has been in operation in the Soviet Union since 1967.

For more than 13 years now, 2-3 "Meteor" satellites have been working in orbit at the same time. Two times a day they "examine" our planet, each time collecting information on cloudines and the thermal radiation rising from the Earth for about 70-80 percent of its surface. Thanks to these "eyes in space," meteorology has begun to see clearly, in the literal sense of that phrase.

The space meteorological system continues to be improved on a continuous basis. In order to obtain operational information, improved "Meteor-2" second-generation satellites are used. In particular, the capabilities for transmitting information about the meteorological situation along the flight path have been improved. This makes it possible, with comparatively simple equipment, for all interested forecasting agencies, airports and ships to obtain photographs of their area when a satellite passes over them.

On the basis of the "Meteor" satellites, our industry has developed the "Meteor-Priroda" satellites, information from which is used in different branches of the national economy.

The Main Center for the Reception and Processing of Satellite Data has been established as part of the USSR State Committee for Hydrometeorology and Environmental Control's system. It processes operational information received from "Meteor-Priroda" satellites, picks out the required topics, and sends information to consumers in the form of images on photographic paper or duplicate negatives, or on magnetic tape, for further circulation and processing inside the organizations themselves. The center already services more than 80 organizations belonging to about 20 ministries and departments.

Geology

Moscow IZVESTIYA in Russian 4 Oct 82 p 2

[Article by V. Kozlov, chief geologist, "Aerogeologiya" association: "The View From on High"]

[Text] Space photographs attracted the attention of geologists immediately. Pictures of the Earth's surface that were obtained with the help of satellites became an important tool for gaining knowledge about parts of the Earth that contain deposits of useful minerals. Prospectors in the depths of the Earth are the main consumers of space information about the natural resources of our planet. From the first experiments to determine the possibilities offered by space photographs there was a rapid transition to their extensive use in geology. When working with space photographs a somewhat paradoxical--or so it seemed--thing was discovered: the higher the viewing point was, the deeper the Earth's geological structure could be seen.

Investigating the structure of extensive areas of the Earth's crust with the help of space photographs and going from the general to the particular in their constructions, geologists had an opportunity to supplement substantially their concepts of the structure of many regions where deposits of useful minerals are concentrated and extensive geological surveying work is being carried out. A cosmogeological map of the entire Soviet Union has been compiled on the basis of photographs from orbit. Specialized cosmogeological maps have been created for almost one-third of this country's territory. The first ones were compiled for the region of the Baykal-Amur Main Line and many regions of intensive national economic exploitation in Siberia, the Far East and the Far North.

By the 25th anniversary of the launching of the first artificial satellite in the USSR, orbital geology had to its credit new ore manifestations of valuable types of mineral raw material, previously unknown ore zones and nodes, and promising areas for the conduct of priority prospecting work.

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AEROSPACE PHOTOGRAPHY IN THE SERVICE OF GEOLOGY

Moscow TEKHNIKA I VOORUZHENIYE in Russian No 4, Apr 82 pp 2-3

[Article by USSR Deputy Minister of Geology V. Volkov]

[Text] Among the methods of studying the geological structure of the earth and its mineral and raw material resources, aerospace photography presently occupies one of the leading places. Using sensing equipment installed aboard spacecraft and airplanes (photographic, photoscanning, television, radiometric etc.), we can simultaneously study large geological bodies and structures, and analyze their relationships in space. The information we obtain helps us to establish the laws of mineral distribution and reveal areas in which new mineral deposits might be discovered. By subjecting high altitude and space photography to geological analysis we can obtain information on the structure and composition of not only deposits near the surface but also rock lying much deeper down.

We can increase the volume of information we obtain by reducing the survey scale, increasing the coverage of each frame and employing a technique known as natural generalization of natural objects (using minute clues to draw up a general geological map). It is precisely owing to this--the use of space photography ensuring a high degree of generalization--that it has become possible to study new classes of geological objects, the dimensions of which attain hundreds and thousands of kilometers and which are sometimes beyond detection even by deep drilling. Such objects include buried folds, all sorts of tectonic blocks, major fault zones and numerous ring formations. Information on such objects is important to establishing the laws governing mineral distribution and to studying the structure of the earth and the history of its development.

Some mineral deposits and fields of altered rock surrounding them cause variations in the spectral characteristics of the surface. These variations can be detected by photography within narrow zones of the visible spectrum (by multizonal photography) or beyond it, in the infrared, radio-wave and other ranges. In such cases minerals can be sought by remote methods. The scientific research, experimentation and experimental production being conducted by organizations within our sector make it possible to clearly determine the range of geological problems that can be solved with remote sensing materials, to develop the methods of their use and to introduce these methods into practice. The numerous geological problems that may be solved effectively with remote sensing materials fall into four basic groups: performing surveys or, as geologists refer to them, regional geological mapping and compiling regional predictions of the locations of minerals in an area covering hundreds of thousands of square kilometers; predicting the local distribution of minerals and prospecting for them in promising areas covering tens and even hundreds of square kilometers; studying hydrogeological and geological engineering conditions and, finally, performing geological analysis of water basins.

The first group of problems includes creation of specialized cosmogeological products (cosmogeological, cosmotectonic and cosmomineralogenic maps), verification of analysis results on the ground and correction of geological maps drawn up without the help of aerospace photography.

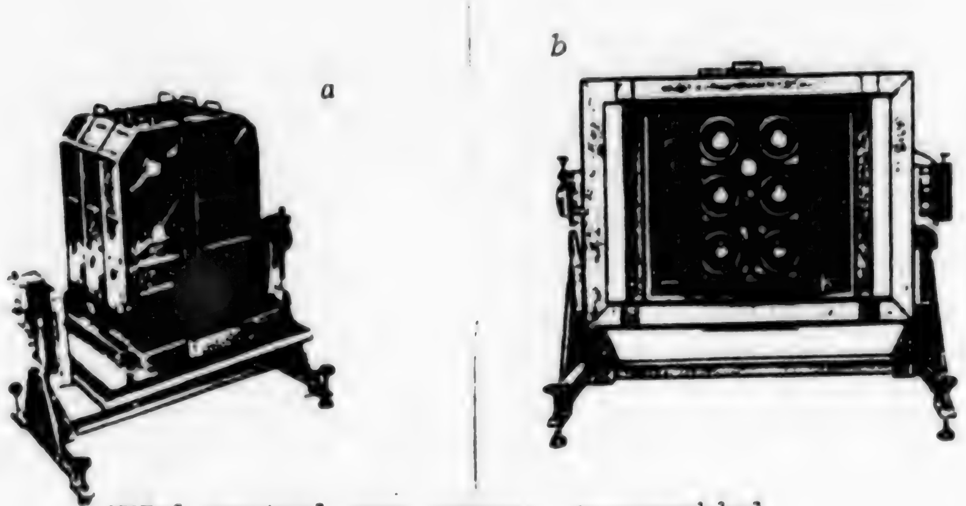
Highly important material and structural elements of the geological structure of large regions, including ones that were formerly unknown, reveal themselves on small-scale cosmogeological maps drawn up on the basis of information obtained from space photographs. Thus such maps provide a firm basis for planning medium- and large-scale geological survey operations in areas most likely to contain mineral deposits. In a number of cases the areas in which prospecting and exploration should be subsequently organized (specialized in terms of particular raw materials) reveal themselves as early as in the map making stage. In recent years cosmogeological maps have been compiled for territories along the route of the Baykal-Amur trunkline, the Soviet Far East and Northeast, the Kola Peninsula and Karelia, and East and West Siberia.

Cosmotectonic maps are an effective tool for studying petroleum and gas bearing provinces. Using them, we can break the land down into regions in terms of the prospects they offer, and distinguish oil- and gas-containing structures of different ranks, among which local structures are the most favorable for formation of exploitable accumulations of oil and gas. By revealing the laws governing the distribution of these deposits, we can more effectively organize drilling and geophysical oil and gas prospecting operations. Many potential oil and gas bearing structures have been detected owing to photography covering West Siberia, western Kazakhstan, Central Asia and the Ukraine.

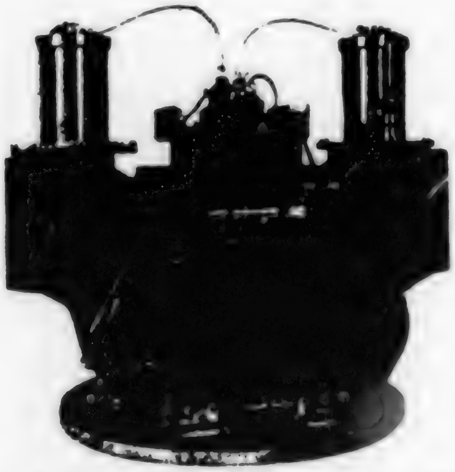
Cosmomineralogenic maps help us to study the relationship between the distribution of solid mineral deposits and objects detected on photography. This form of work is especially effective in inaccessible regions that have not been studied very deeply, inasmuch as it provides a way for reducing the time between regional analysis and detailed prospecting and exploration.

Medium- and large-scale geological maps require analysis of aerospace information for their compilation. Owing to such analysis the maps are more detailed and accurate, and they can be compiled faster. The mapping work can be organized more effectively: Maps can be created by the efforts of a single collective not by successively enlarging the mapped area (by drawing up geological map sheets one at a time) but by purposefully increasing the detail of observation within a large area (covered by 10 or more sheets). In this case aerospace information provides invaluable assistance by tying in isolated observations made during terrestrial explorations. Concurrently, the objectivity of the geological maps rises. It should be noted that introduction of this method has significantly increased the rate of geological analysis of the country's territory and reduced, by an average of 20 percent, the outlays to study a single square kilometer of the surface.

Regional geological surveying and exploration sometimes reveals a large quantity of "cosmogeological objects" for which the origins and significance are not always clear. In these cases the analysis data are subjected to special ground verification with the purpose of clarifying the geological nature of these objects. Such verification of a "cosmogeological object" includes a complex of geological-geophysical, geochemical and laboratory studies. In particular, these studies provide a bridge between regional predictions of the locations of minerals and local predictions, and they help to pinpoint the specific areas in which prospecting and explorations should be conducted in detail. In this case the task of aerospace photography is to reveal new, formerly unknown laws in the distribution of minerals, and in the final analysis to narrow down the front of explorations, which could now be concentrated in the most promising areas.



MKF-6 spectral zone camera: *a*--assembled camera; *b*--view facing objectives



A new instrument for remote analysis of the thermal field of the earth surface--the "Vulkan" airplane thermal sensor.

Economic development of new regions, to include Siberia and the Far East, necessitated creation of sets of hydrogeological and geological engineering maps as a basis for planning engineer structures and water supply systems for new cities, worker settlements and agricultural land. Aerospace information obtained for these purposes provides the following advantages: More efficient distribution of the network of wells; integrated analysis of underground water sources, channels and outlets; establishment of the distribution limits, composition and, in some cases, the thickness of recent loose formations; creation of geological engineering maps of rock formations and of modern geological processes, and some other practical problems. For example the data obtained thus far are being used successfully to select the locations of bridges, quarries, water diversion channels and other objects along the route of the Baykal-Amur Rail Trunkline. A number of new hydrogeological structures have been discovered in the Turgayskiy region, in the Kolyvan'-Tomsk zone and in other regions.

Geological investigations of water basins by remote photography, when combined with data obtained from underwater and geophysical operations, can be used to solve a broad range of problems. They essentially boil down to the following: Providing an accurate plan view of the location of various geological and geomorphological objects; clarifying the shape of the undersea relief, which may be interpreted variously from profile measurements; revealing geological structures and tectonic disturbances of different orders of magnitude; studying the dynamics of the movement of alluvial deposits in the coastal zone. Aerospace information is especially important to studying shallows and tidal zones which are inaccessible to marine geophysical vessels. Moreover aerospace information has proven itself as an aid to compiling maps of the possible locations of raw materials such as oil and gas, minerals and construction materials in the Bering, Okhotsk, Black, Caspian and Aral seas.

Aerospace photography is of invaluable assistance to nature conservation measures. Such measures have been made necessary by the growing scale of geological explorations and mining activity. Retrospective analysis of remote sensing materials has made it possible to efficiently and reliably predict changes in the environment. For example according to expert estimates, use of these methods to recultivate just one of the small areas of the Kursk magnetic anomaly has produced an economic impact of about 0.5 million rubles.

These examples attest to the enormous practical significance of aerospace information in geology. At the same time this information also helps theoretical geologists. Thus its use has made it possible not only to reveal new classes of geological objects but also to initiate a new direction of geological science--comparative planetology.

Multifactor analysis of obtained materials would be unimaginable without its automation on the basis of modern computer technology. This is why the sector's enterprises are now making use of the "Format" automated system based on series YeS computers, and why we have developed the "Region" system, which operates in interactive (man-machine) mode.

If we are to make more effective use of aerospace information in the future, our sector's workers will have to solve a number of important methodological, technical and organizational problems. Thus we need to improve the process of analysis, which is sometimes based on the intuition of individual analysts. Objective end results could be achieved by integrating the analytical data with other geological and geophysical materials.

Another problem is associated with ground verification of analysis results. Because the cosmogeological objects we reveal are far apart and diverse in nature, we need to create mobile ground stations outfitted with a complex of geological and geophysical apparatus that would operate dependably even in extreme natural conditions. Prototypes of such resources--wheeled and tracked exploratory-survey stations--have recently been developed.

There can be no doubt that the possibilities of using aerospace technology in geology are far from exhausted. Each new space launch enriches geologists with important information. Our sector's laborers are fully resolved to complete the grandiose tasks of developing our country's mineral and raw material base, as posed by the 26th CPSU Congress, and to honorably greet the 60th anniversary of the formation of the Union of Soviet Socialist Republics.

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'METEOR' WEATHER SATELLITES

Moscow AVIATSIYA I KOSMONAVTIKA in Russian No 11, Nov 82 pp 44-45

[Article by N. Kon'kov: "The 'Meteors' Keep Watch"]

[Text] "Space Hydrometeorology for the National Economy" is the title of a thematic exhibit at the VDNKh SSSR [Exhibition of Achievements of the National Economy of the USSR]. Illuminated panels stand out along the walls of the USSR "Gidrometsluzhba" [Hydrometeorological Service Main Administration] pavilion. A group of visitors came to a stop near the displays in the section entitled "Satellites: for the Weather Service and the National Economy." They were explained by methodologist Natal'ya Vital'yevna Tereshina:

"Today farmers expect warnings about possible freezes; sailors about an impending storm; pilots--including polar ones--data on wind direction and force, temperature, zones of turbulence, the nature of the cloud cover at the flight altitude. Without this information, no crew will leave on a scheduled flight. Not only the forecasts themselves, but also their accuracy and operational nature are important. Therefore, meteorologists are interested in information on how the cloud cap is distributed above the globe, what is the concentration of polluting impurities in the atmosphere and hydrosphere, and what is the status of the ozone layer. Satellites, keeping their vigilant watch from orbit, are of great assistance in finding out these things."

In order to formulate a reliable weather forecast, it is necessary to have operational information about the state of the entire layer of atmosphere, the ocean and the Earth's surface. It is possible to predict weather several days in advance if there is information available about meteorological processes taking place over at least half the globe. The development of forecasts for long periods requires global information, and only meteorological satellites are capable of obtaining operational data on the state of the atmosphere, cloud cover and land and ocean surfaces.

Almost 12,000 meteorological stations and posts and 10 weather ships located at various points on the world ocean are engaged in probing the atmosphere on an around-the-clock basis. The operational information received from satellites helps the large army of meteorologists to determine more accurately the weather-forming processes over the oceans and hard-to-reach land areas, which occupy four-fifths of our planet, and to compile more accurate weather forecasts. It is difficult to overestimate the value that satellites have acquired as far as meteorological support for flights over the long-distance air routes on our continent and, in particular, for intercontinental flights. As far as regions with a dense network of ground meteorological stations are concerned, there satellite data make it possible to make corrections in weather map analyses.

Experiments in obtaining meteorological information with the help of satellites began in the Soviet Union in 1966, with "Cosmos-122." Since 1969 meteorological satellites have been considered an independent class of spacecraft and have received the name "Meteor." At the present time the "Meteor" system consists of two or three meteorological satellites and information reception, processing and dissemination centers located in Moscow, Novosibirsk and Khabarovsk, as well as services for monitoring the status of the satellites' on-board systems and controlling them.

"Before you," continues Tereshina, "is an entire small town. This is a model of the Far Eastern Regional Processing Center's Satellite Information Reception and Transmission Point. The 'Fobos' rectangular antenna, located on that building, seems small. In actuality it has an area of more than 100 square meters and is always aimed at space. The antenna can capture the very weakest electronic noise. Since the sky in the vicinity of large cities is usually filled with the noise of various electrical devices that are in operation, the receiving point with the "Fobos" is located outside Khabarovsk."

Listening to the methodologist's story, the visitors imagine themselves in a building at the receiving point during a regular communication system. Over here the screen of a video monitoring unit has lit up. "Meteor-2" is approaching Khabarovsk at this moment. The satellite's on-board tape recorders have been gathering information during the orbit and now must transmit it to the reception point during the few minutes it is in the radio-visibility zone. A rapid sequence of conventional signs appears on the monitors' screens. After processing they are converted into data on meteorological parameters or photographs of different regions of our planet.

"Soviet scientists and engineers," our methodologist says further, "have built modern television equipment. Literally 5-10 minutes after the satellite has passed, at the reception point there is a photograph of the cloud cover and underlying surface for an area of several million square kilometers. These images preserve all the freshness and urgency of the current moment for the forecaster-meteorologist."

It should be added here that information on cloud cover transmitted from satellites is important for aviation, particularly during flights over intercontinental routes. Here is a typical example. The regular arrival of satellite information on weather conditions played a significant role in determining the possibility of opening new aviation routes. Moscow-Maputu-Molodezhnaya in 1980 and Khabarovsk-Hanoi in 1979.

Before the satellite appears on the next revolution of its orbit, all the information received must be completely processed and represented in the form of graphs and maps suitable for use in the operational weather service. Therefore, the receiving point is equipped with computers and automatic equipment, since it is impossible to process these vast information flows manually.

Satellite data make it possible to define zones of storm-caused wave action in the ocean and to formulate recommendations for selecting the most suitable routes for ships.

"Look at the ship 'Kapitan Teplov,' and how the pointer is floating over the map. Did it succeed in missing the dangerous region where the tropical hurrican 'Francis' was raging? Using the recommendations of the USSR Gidomettsentr [Hydrometeorological Scientific Research Center], the crew chose the most rational route. This insured not only safe sailing, but also shortened the travel time, which produced a substantial economic effect."

The group of visitors moves on to the next section of the exhibit: "Important Results of Scientific Research in the Field of Space Hydrometeorology."

"I foresee a question: why are there so many cloud photographs in the panels?" Tereshina turned to the visitors. "The fact of the matter is that man long ago noticed a connection between the nature of the cloud cover and the weather. This was consolidated in accurate popular sayings. Satellites produced new information that made it possible to formulate a more nearly complete picture of the distribution of cloud cover over the Earth's surface. In and of itself, this is very important for evaluating the actual state of the weather."

But the atmosphere can tell the "Meteors" much more than that about itself. Here we are talking about how, literally in just a few minutes, with the help of special equipment it is possible to obtain data on the temperature, amount and distribution of water vapor in the atmosphere, the water content of clouds and their altitude, thickness and temperature, and wind speeds at altitudes of several kilometers. Science and technology approached the solution of this complex problem in earnest with the help of remote sensing of the atmosphere.

Remote sensing is possible in any weather and at any time of day. This is its advantage. In combination with optical, radar and sonic sounding, it makes it possible to obtain a quantity of new information about the state of the atmosphere, such as the amount of carbon dioxide, smoke pollution and the presence of harmful impurities.

One of the special features of "Meteor" satellites is observation of forest resources. Every day, photographs of this country's entire forest zone are sent over telecommunication channels from the satellites. They are used to evaluate the fire-danger situation and the dynamics of the development of fire nuclei.

"Turn your attention to this photograph," says the methodologist. "As you can see, the nuclei of large fires are quite clearly recognizable by the light-gray image of the smoke loops, which are stretched out in the direction of the prevailing wind. Besides this, information about the distribution and development of cloud cover makes it possible to determine the fire hazard. In our countries, forests occupy more than half the land mass. And today practice has already proven that satellites are a necessary link in the integrated system for the remote study of forests in order to administer their resources."

We stop near a panel with materials on the use of satellite data on the ice cover.

"What the satellites report about the ice situation," remarks Tereshina, "is of great practical value for ship travel in the Arctic basin. With the development of what is actually year-round travel over the Northern Sea Route, satellite information is becoming even more necessary. For instance, a map of the ice situation with correlational accuracy of ±5-6 kilometers can be compiled with the help of satellite information in 1.5-2 hours, while for the well-covered ground reference points of seas such as the White and the Kara it takes only 20-30 minutes."

The "Meteors" are on watch around the clock. The information they carry is valuable not only for hydrometeorology: television and infrared photographs from space also help in the study of the Earth in the interest of the national economy.

"Economics should be economical!" Everyone connected with space hydrometeorology is constantly being reminded of this slogan, which was advanced by the 26th party congress. The proof of this are the materials presented in the exhibit. They are indicative of the efforts of every specialist to achieve a maximal increase in the economic effectiveness of the use of the material obtained in the national economy and to greet the 60th anniversary of the founding of the USSR worthily.

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POSSIBILITY OF CHANGING LIMITS OF SPECTRAL RANGES IN REMOTE INVESTIGATIONS OF EARTH

Moscow ISSLEDOVANIYE ZEMLI IZ KOSMOSA in Russian No 4, Jul-Aug 82
(manuscript received 4 Jun 81) pp 66-71

ANDREYEVA, N. I., IVANOV, S. A. and CHAPURSKIY, L. I.

[Abstract] In some practical cases difficulties arise in achieving the necessary spatial or energy resolution of images obtained by multispectral apparatus operating in the spectral region 1-2.4 μm, such as in the case of presence of limitations on response of the radiation detectors. In this article it is shown that these difficulties can be overcome without changing the parameters of the objectives and with the same radiation detectors, but using broader spectral intervals. It was necessary to determine to what extent it was possible to broaden the limits of the spectral intervals in the near-IR region and the extent to which the conditions for discriminating natural features change under these conditions. In solving this problem the authors made computations of the signals at the output of radiation detectors which can be used in registering signals in different intervals of the spectral range from 1.2 to 2.4 μm, taking into account atmospheric transfer properties. The computations were made using the spectral brightness coefficients of chernozem, steppe and grass, as well as fields of grain crops in different stages of maturity. PbS, Ge and InAs radiation detectors were used. Filters with a π-shaped spectral transmission characteristic were used and the transfer function of the objective did not change with time. A comparative evaluation of the conditions for observing the earth's surface in individual subranges in the near-IR range indicated that with respect to solution of problems in recognition of the principal classes of natural features the broadened spectral range 1.24-2.4 μm corresponds qualitatively to the range 1.55-1.75 μm. With its use in place of the ranges including only the transparency windows with centers near 1.6 or 2.2 μm the energy gain attains a factor of 2.5-3 or 9 respectively. The parts of the spectrum corresponding to the wings of the water vapor absorption bands are informative in solving problems in the recognition of natural features. Therefore, in case of necessity it is possible to increase the energy or spatial resolution of one or more channels of multispectral apparatus. In arriving at

this conclusion the authors have not taken into account such factors as superposed noise from optical-electronic signal transformation and the diffraction limit of the optical system, problems requiring special examination. Figures 1; tables 3; references 11: 10 Russian, 1 Western.
[6-5303]

UDC 551.46:528.72(202)

SOLVING PROBLEM OF TRANSFER OF OPTICAL IMAGE OF EARTH'S SURFACE IN HORIZONTALLY INHOMOGENEOUS ATMOSPHERE

Moscow ISSLEDOVANIYE ZEMLI IZ KOSMOSA in Russian No 4, Jul-Aug 82
(manuscript received 1 Jun 81) pp 95-104

MISHIN, I. V., State Scientific Research Center for Study of Natural Resources, Moscow

[Abstract] There is a need for developing methods for computing the intensity of radiation in horizontally inhomogeneous layers of a turbid medium, taking into account reflection from a surface with a nonuniform albedo. The solution of this problem is a preliminary stage in constructing a general physicomathematical model of the transfer of short-wave radiation in the real atmosphere. This requires formulation of methods for computing the intensity of radiation not dependent on changes in the scattering coefficient and surface albedo. Accordingly, the author proposes a general approach for computing the spatial distortions of intensity of the light field based on use of functions invariant relative to horizontal variations of the scattering coefficient and albedo of the reflecting surface. The proposed approach is intended primarily for investigating the patterns of transfer of an optical image in the atmosphere. As a simplification it is assumed that the atmosphere is homogeneous in a vertical direction and does not absorb radiation, whereas the surface is Labertian. The method described here involves computation of functions which are not dependent on variations of surface brightness and fluctuations in the density of scatterers. The boundary-value problems which are written can be solved using the known mathematical methods of transfer theory. It is shown that the scattering of radiation in horizontally inhomogeneous layers of a turbid medium and multiple rereflection of photons from the earth's surface leads to the appearance of nonlinear distortions of the optical image. The proposed method is convenient in the mathematical modeling of the process of transfer of an optical image in the earth's surface-atmosphere system since the latter is represented by a set of linear and nonlinear filters of space frequencies. This method, without modifications, can be used in a study of the laws of transformation of the brightness field in horizontally inhomogeneous clouds. References 19: 16 Russian, 3 Western.
[6-5303]

UDC 528.72(202)+502.3

MATHEMATICAL MODEL OF SPACE IMAGE OF EARTH'S SURFACE OBTAINED USING SYNTHETIC APERTURE RADAR

Moscow ISSLEDOVANIYE ZEMLI IZ KOSMOSA in Russian No 4, Jul-Aug 82 (manuscript received 14 Jul 81) pp 105-114

KHIZHNICHENKO, V. I.

[Abstract] Synthetic aperture radars constitute a highly promising means for studying natural resources and mapping the earth's surface. Simplified models, for the most part applicable to the detection of point objects, have been used in describing the radar image. However, high accuracy characteristics of the radar image cannot be ensured without a more detailed model which takes into account the possibility of digital processing of signals. Accordingly, the author proposes a radar image model applicable to a space system for scanning the earth based on a radar with a synthetic aperture with pulsed radiation. The model does not take into account the distortions caused by purely electronic effects. The article examines various problems related to the development of algorithms for the phase, amplitude and geometrical correction of the radar image and a method for evaluating the limiting spatial resolution of a radar with a synthetic aperture. Allowance is made for effects related to the dynamics of motion of an artificial earth satellite and the orientation system, as well as all elements of the process of radar image synthesis based on optimum filtering of the received coherent signal relative to range and Doppler coordinates. A numerical example is given. Suggestions are made for further improvements, particularly elimination of the purely electronic distorting factors. Figures 2; tables 2; references 8: 6 Russian, 2 Western.
[6-5303]

UDC 528.7:535.243

INSTRUMENTATION FOR AIRCRAFT INVESTIGATIONS OF OPTICAL CHARACTERISTICS OF EARTH'S SURFACE-ATMOSPHERE SYSTEM

Moscow ISSLEDOVANIYE ZEMLI IZ KOSMOSA in Russian No 4, Jul-Aug 82 (manuscript received 25 Feb 81) pp 115-121

KOZLOV, Ye. M., Space Research Institute, USSR Academy of Sciences, Moscow

[Abstract] V. V. Badayev, et al. (IZV. AN SSSR: FIZIKA ATM. I OKEANA, Vol 14, No 10, 1978) proposed a multisided method for determining the necessary parameters of the atmosphere and ocean in each specific case of measurement of $I_{\lambda}\uparrow$. For the purpose of checking the operability of the method of Il-14 aircraft was used in making measurements of the optical

parameters of the earth's surface-atmosphere system in several ranges of the visible and near-IR spectral region at altitudes from 100 to 5000 m. A study was also made of the patterns of vertical transformation of the angular, spatial and spectral structures of the brightness field under real conditions which must be taken into account in the interpretation of the results of satellite measurements of reflected solar radiation. The aircraft also carried a measurement complex which included a six-channel filter photometer operating in the spectral region 0.45-0.77 μm with an instantaneous field of view 2° and a time constant 0.01 sec. The design of the photometer makes it possible to carry out measurements of brightness of the earth's surface-atmosphere system $I_\lambda \uparrow$ in natural and polarized light in several fixed sighting directions lying in the plane perpendicular to the longitudinal axis of the aircraft with nadir angular distances 0°-40° and also the brightness of the daytime sky $I_{\gamma\lambda}$ at the almucantar with azimuthal distances from the sun $\varphi_\odot \geq 8°$. Other significant parameters were also measured, such as the optical thickness of the atmosphere lying above the flight altitude H. The photometer, described fully in the text, is illustrated schematically in Fig. 1; a block diagram of the innovative instrument complex for aircraft investigations of optical characteristics is shown as Fig. 2. Represenative results are given with clear indication of the need for correcting the results of remote sensings of the ocean in accordance with the optical state of the atmosphere at the time when the measurements are carried out. Figures 4; references: 12.
[6-5303]

UDC 551.46.0:528.7

USING CIRCULAR (CONICAL) SCANNING FOR OBSERVING OCEAN AREAS IN OPTICAL RANGE

Moscow ISSLEDOVANIYE ZEMLI IZ KOSMOSA in Russian No 4, Jul-Aug 82 (manuscript received 8 Dec 81) pp 122-124

SELIVANOV, A. S. and GEKTIN, Yu. M.

[Abstract] Circular (conical) scanning is examined applicable to problems involved in observation of ocean areas; modifications of such systems have been used on the "Skylab" station and on the "Meteor" satellite. An adequately complete system for the scanning of ocean areas must ensure the possibility of observations both in the frontal and rear zones. The following are some of the most important advantages of circular scanning. It is not sensitive to many factors which impair the operability of other systems and does not require complications of on-board instrumentation for operation under any conditions. The system has little sensitivity to annual changes in illumination conditions. There is a higher radiometric accuracy since observations of each surface element are made at an identical angle; there is a constancy of resolution in the entire scanning line and an identical

influence of the atmosphere for all image elements. The signal from the same surface sectors is obtained virtually simultaneously in the frontal and rear scanning zones. The joint processing of these signals makes it possible to identify the observed objects, especially surface and atmospheric phenomena (observation of the first is dependent on angle, whereas observation of the second is not). There is an increase in the reliability and accuracy of temperature measurements. Stereoscopic images can be obtained. These and other factors made circular scanners ideal for the surveying of ocean areas. Figures 1; references 4: 3 Russian, 1 Western.
[6-5303]

SPACE POLICY AND ADMINISTRATION

CONTRIBUTIONS OF REPUBLIC INSTITUTES TO SPACE RESEARCH

Tallinn SOVETSKAYA ESTONIYA in Russian 28 Dec 82 p 3

[Article by Yu. Zaytsev, department chief, Institute of Space Research, USSR Academy of Sciences: "On the Forward Edge of Science"]

[Text] The development of science in our nation has always been a matter not only for scientists, but also for the party and the people as a whole. The joining of the Soviet republics into a unified, friendly family enjoying equal rights contributed to the USSR's advancement into the leading position in the world in many important fields of the scientific and technical revolution. A diversified network of institutes and research centers has been created.

Epochal results have indeed been achieved in the study and conquest of space. Scientific organizations in almost all the union republics are participating in this work.

A few years ago, the socialist countries held an international seminar on the subject "Scientific Instrument Building for Use in Space" in Frunze, the capital of Kirghizia. Did this surprise anyone? Not at all! It was recognized as something that was bound to happen. And why not have it in Frunze, which has its own Academy of Sciences, several thousand scientific workers and dozens of scientific research organizations, including the Special Design Bureau of the USSR Academy of Sciences' Institute of Space Research? The instruments created by the scientists of Kirghiziya have been used in near-Earth orbits and in deep space.

Most of you readers have probably seen the color pictures of Venus's surface that were transmitted to Earth by the "Venera-13" and "Venera-14" stations. What you probably do not know is that during the tests, these stations' television cameras were dropped onto concrete from a helicopter at an altitude of 300 meters. After this the cameras had to work normally! Such are the requirements for space instruments: severe limitations on weight, volume and power requirements and, at the same time, the very highest reliability.

And the "Groza" instrument that was installed in these same stations? It functioned normally in 500° heat, under 100 atmospheres of pressure, throughout the entire time of the descent module's existence. During this time its sensitivity was so high that it made it possible to record the noise of the wind on Venus's surface on an acoustic channel. Together with its antenna the instrument weighted only about 1,300 grams and required about 1 watt of power.

As an example demonstrating the creative labor of the workers at the Design Office in Frunze we can also present the "Fragment" equipment, which is used to study the Earth's natural resources from space. For more than 2 years now it has been functioning successfully on board a satellite. The amount of information obtained with its help now measures thousands of kilometers of magnetic tape and millions of square kilometers of investigated areas of the Earth's surface.

One of the most recent results of the work of the Kirghiz designers is the creation of an on-board cosmic gamma-ray telescope, the sensitive area of which is almost 1.5 square meters. This is triple the area of the analogous American instrument. This achievement is particularly impressive when one considers that Kirghiziya was at one time one of the most backward, outlying districts of tsarist Russia.

An extensive program of investigations and experiments is being carried out by the Baku Institute of Space Investigation of Natural Resources of the Azerbaijan SSR Academy of Sciences. Today it is the socialist countries' leading organization for the taking of subsatellite measurements in so-called test sections. In order to carry out these assignments, the institute has a solid base: land and sea testing grounds, a number of laboratories, the most modern equipment and instruments. The institute works closely with more than 20 scientific establishments in our country and many organizations in the socialist countries on the development of various scientific, technical and applied problems that are of importance for the national economy. In particular, the Azerbaijani scientists have developed an experimental prototype of an automated system for subsatellite measurements. This system was tested successfully on the testing grounds of the socialist countries during the flights of the international crews as part of the "Intercosmos" program. When flying over the territory of their own countries, the cosmonauts knew that directly beneath the "Salyut-Soyuz" orbital complex and at the same time, the same section of the Earth was being surveyed by the subsatellite complex, which consisted of an AN-30 airplane as the "flying laboratory" and a "laboratory on wheels" developed in Baku.

An experiment named "Georgia-60" was recently conducted in space in honor of the Georgian SSR's anniversary and the 60th anniversary of the founding of the Soviet state. The rocket rose to an altitude of more than 1,500 kilometers, and the weight of the probe and its instruments was 1,300 kilograms. For the sake of comparison, in the "Araks" experiment a French "Eridan" rocket rose to an altitude of only 130 kilometers, and the scientific equipment's weight did not exceed 400 kilograms.

We should emphasize that the Georgian scientists are not newcomers to space research. However, although previously the research was done solely from the surface of the Earth, now it is being done directly in space and, in connection with this, by the most progressive methods. In the last few years alone, Georgian specialists have developed about 10 on-board instruments for space experiments.

The achievements of Armenian astrophysicists are known to the entire world. The activities of the Byurakan Astrophysical Observatory are highly esteemed both in our country and abroad.

However, the possibilities of terrestrial astronomy are fundamentally limited because of the interference of the atmosphere. Calculations show that a telescope with a mirror diameter of 1 meter, operating in space, will be as efficient as the largest terrestrial telescopes: the 5-meter Palomar telescope in the United States or the 6-meter mirror installed at Zelenchuk in the North Caucasus. One of the first attempts at this was made when the "Orion" telescope, built by scientists from the Garniyskaya Laboratory of Space Astronomy in Armenia, which was sent to the "Salyut" station in space. Although the diameter of this telescope's mirror was only 24 centimeters, the results of the experiment exceeded all expectations.

Today Soviet scientists are working on the creation of an ultraviolet space telescope with a mirror 80 centimeters in diameter. When it is in operation it will become a new and important stage in our knowledge of the world around us.

The Tyravereskaya Observatory in Estonia appears to be more modestly equipped than the Byurakan Observatory, although they are of the same age in the space era, but it is there, in Tartu, where the World Special Geophysical Center for Noctilucent Clouds is located, and its work is done by Estonian scientists not only from Earth, but also from altitudes above the clouds.

First of all, why are scientists interested in noctilucent clouds?

It can be assumed that in these astonishing formations, somewhere on the boundary between the air ocean and space, there lies the key to the great mystery of the processes that take place in the upper atmosphere. The study of these processes, which determine the climate and life on Earth to a significant degree, is one of the most important problems of modern science.

Noctilucent clouds were first investigated from a spacecraft--the Soviet "Salyut-4" orbital station--in 1975, by cosmonauts Petr Klimuk and Vitaliy Sevast'yanov. Estonian scientists developed the "Mikron" equipment for this purpose. The clouds were not only photographed, but were also subjected to spectrography, which is an example of how observations from the window of a spacecraft can produce scientific information that cannot be obtained during many decades of the most intensive observations from the surface of the Earth. The investigation was then continued by the "Salyut-6" and "Salyut-7" stations. Yuriy Romanenko and Georgiy Grechko observed noctilucent clouds over the South Pole. The space observations confirmed the multistage nature of the clouds and showed that fields of noctilucent clouds can have global scales at latitudes above 45°, in addition to making it possible to draw a number of other conclusions that are very important in attempting to understand their nature.

"Heavenly searches" and purely practical terrestrial matters: this is how Professor Yuriy Shafer characterized the activities of the Institute of Cosmophysical Research and Aeronomy in Yakutsk, which he heads. This city, which was a prison without bars in tsarist Russia, has now become one of the centers of scientific thought. Here there is a branch of the Siberian Department of the USSR Academy of Sciences, as well as the most powerful installation for the registration of cosmic rays in the Soviet Union. Its effective area is more than 20 square kilometers.

Our own star is also a source of cosmic rays. When flares occur on the Sun, the cosmic rays are accelerated to huge energies and powerful waves from the solar storms reach our planet. The quiet pattern of processes in the Earth's atmosphere is then disrupted, short-wave radio communication ceases, compass needles swing wildly, and polar auroras appear.

Solar activity also affects the most variegated biological processes. It is a well-known fact that on days when solar storms are raging, the condition of people with cardiovascular and neuropsychic illnesses deteriorates. The relationship between flares and such phenomena as injuries at work, an increase in criminality and many other things is being followed. The Sun gives us life and affects it in ways that are largely unknown to us. Nevertheless, scientists are already successful in predicting storm activity quite accurately. Every day the space physicists in Yakutsk make forecasts for doctors, first aid stations and communicators. The sensitive instruments built by them continually register the cosmic radiation moving toward the Earth and into its magnetosphere and atmosphere and track the polar auroras.

In this article there are only a few examples of the participation of scientists from the union and autonomous republics in the preparation for and conduct of space research, but they say a lot. First of all, they are an indicator of the high scientific and technical potential achieved during the years of Soviet power and evidence of the wisdom of the Leninist national policy, which has opened to all the peoples of our Fatherland limitless possibilities for comprehensive development.

11746
CSO: 1866/70

KOTEL'NIKOV ON RECENT SPACE ACCOMPLISHMENTS

Moscow AVIATSIYA I KOSMONAVTIKA in Russian No 11, Nov 82 pp 22-23

[Article by Academician V. Kotel'nikov, vice president, USSR Academy of Sciences; chairman, "Intercosmos" Council: "Orbits of the World and Progress"]

[Text] Since the moment the first artificial Earth satellite was launched and the practical conquest of space began, 25 years have passed. The road we have traveled during this period is a very long one.

On 12 April 1961 the world was notified of a remarkable event in the history of mankind. Having overcome terrestrial gravity, the first person from out planet, Yuriy Alekseyevich Gagarin, a citizen of the Soviet Union, flew around the world in a space ship.

The 21 years that have passed since this event were filled with intense and fruitful work. Manned spaceflight, which was once an exceptional event, became an almost commonplace phenomenon. The sphere of scientific research utilizing spacecraft was expanded. Space technology functions in the national economy on ever-increasing scales.

The 26th CPSU Congress formulated new goals for us, including some having to do with the conquest of space.

The subject of this article is recent events in the field of space research.

For 676 days, 5 main expeditions and 11 visiting crews worked on board a space station. For the first time in history, nine cosmonaut-researchers from the socialist countries that are participants in the "Intercosmos" program--the Czechoslovakian SSR, the Polish People's Republic, the GDR, the People's Republic of Bulgaria, the Hungarian People's Republic, the Socialist Republic of Vietnam, the Republic of Cuba, the Mongolian People's Republic and the Socialist Republic of Romania--worked in space.

This cycle's basic goals were as follows: to study the Earth, its atmosphere and other cosmic objects from space, to investigate a number of physical and biological processes in weightlessness, as well as the human body during and after spaceflight, and to improve space technology.

The flights in the "Salyut-6" station, in which 27 cosmonauts participated (six of them went into orbit twice, and two--L. Popov and V. Ryumin--made the longest flight), yielded a large amount of valuable information for medicine and for increasing the efficiency of man's functioning in space.

The question is sometimes asked: do we really need to send man into space? Actually, it is feasible to assign much research in space to automata. In a number of cases this is both cheaper and safer. However, the presence of man, particularly in the early stages of the development of techniques, makes it possible to carry out an assignment much more rapidly and completely. Therefore, we now continue to think that it is necessary to use both manned flights and automata.

Of the experiments that were conducted on board "Salyut-6," I would like to focus special attention on the radio engineering ones.

As is well known, submillimeter waves (their length is less than 1 millimeter) do not pass through the atmosphere, but to us it is very important to know what is happening in this band. Therefore, the BST-1M telescope was used on board the "Salyut-6." One of the interesting results was the detection of anomalously strong emissions in the submillimeter band in the area of thunderstorm formations. In addition to this, the experimental technique was worked out. The fact of the matter is that the BST-1M's radio wave receivers are cooled by liquid helium, which is always boiling. Under conditions of weightlessness it was important to overcome the difficulties related to this process.

Another radiotelescope, the KRT-10, was for waves with lengths measured in the tens of centimeters. They pass through the atmosphere quite well, and this makes it possible to organize the observation from space of the radio waves emitted by the Earth, by day or by night and in any weather. By studying radio waves we have now learned how to determine the temperature of ocean water with an accuracy of about two degrees, as well as wave action, soil moisture (with up to 10 percent accuracy), the atmosphere's water vapor content and water contained separately in the atmosphere in the form of droplets in clouds and storm clouds. These data will be of great importance for the compilation of weather forecasts and the understanding of the processes that determine it.

The basic purpose of space radiotelescopes is to observe small and very remote objects in space. On Earth, by placing radiotelescopes on different continents we have succeeded in achieving angular resolution of 100 million radians, which is better by three orders of magnitude (or a factor of 1,000) than for optical telescopes, and corresponds to objects several meters in size that are as far from us as the Moon. Astronomers want to examine even smaller objects, so the KRT-10 was sent far beyond the Earth's boundaries, to the orbital station.

On the "Salyut-6" an important place was given to visual observations of the Earth's land and water surfaces and photographing them with special cameras that produce color images. The cosmonauts determined what to photograph and how best to do it. Tens of thousands of pictures were taken.

The cosmonauts discovered a number of previously unknown faults in the Earth's crust and studied its jointing in several places, as well as regions promising for oil and other useful minerals. The materials that were obtained have already been used to compile a new tectonic map of the USSR. The observation of volcanoes in the Kuril Islands from space indicated that some of them that were considered to be extinct may be activated.

There was a large program concerning so-called space technology. The cosmonauts conducted one part of the experiments in order to determine the essence of certain physical phenomena, whereas another part of them were for the development of a new technology for the production of valuable materials needed for manufacturing purposes, such as miniaturized elements for communications electronics instruments.

Finally, the "Salyut-6" program was concerned with testing and checking transport ships and the station itself and with determining the possibility of repairing it during a flight. The results that were obtained were taken into consideration in the design of the "Salyut-7," which has now received the baton in the stellar relay race.

An important event of this year was the flight of the Soviet-French crew on a Soviet manned ship and in the orbital station. Experiments were conducted with new scientific instruments manufactured in the USSR and France.

A great success for our science and space and instrument building technology was the flight to Venus of the "Venera-13" and "Venera-14" stations and the landing from them, at the beginning of March of this year, of automatic equipment on Venus's surface.

Why are we concerned with this planet? By studying Venus, we hope to solve several mysteries of the Earth. Scientists are interested in both the past (it should help us understand the present better) and the future of our planet. Until now we were able to do this only on the basis of the study of terrestrial processes. Now there has appeared the possibility of studying the situation on another planet that exists under similar conditions.

What did the most recent Soviet expeditions to Venus yield? First of all, there were further investigations of the atmosphere. The first measurements that were made of the ultraviolet part of the flow of solar radiation showed that a considerable part of it is absorbed at altitudes above 60 km, where it heats the atmosphere. This possibly explains the unusually rapid revolution of the cloud cover, which exists primarily at these altitudes.

The first measurements were also made of the content of all the inert gasses in the atmosphere, as well as many of their isotopes. This is very important information for planetology.

The atmosphere's water vapor content was measured by different methods. For reasons not yet understood, it turned out to be very low. By direct methods it was demonstrated that sulfur is the basic element in the cloud layer. As it turned out, Venus's sky is orange, so everything has an orange cast. This is explained by the fact that that planet's atmosphere absorbs blue rays or, more precisely, the blue part of the spectrum.

Information about the planet's surface is of the greatest interest. Black-and-white photographs with better resolution than before were obtained, along with the first color photographs of the vicinities of the landing sites. Soil samples obtained with a drill were transferred through an air lock into the evacuated space of the analyzer of an X-ray fluorescence spectrometer. The spectra obtained (about 60 of them) were transmitted to Earth via radio.

Analysis of the spectra produced data on the soil's potassium, magnesium, silicon, aluminum, calcium, titanium, manganese and iron content. Further analysis of the spectra is being carried out in order to determine what elements are contained in lower concentrations.

The rock in the area of the landing of the "Venera-13" station's module has been classified as leucitic basalt that has undergone chemical weathering. This agrees with the appearance and texture of the rock seen in the panoramas.

Knowledge of the soil's chemical composition will enable us to calculate its primary mineral composition and the composition of secondary minerals that have appeared under the effect of Venus's aggressive atmosphere on the soil, in addition to determining the conditions for the formation of the original melt, the depth of its deposition and the degree of melting of Venus's mantle in connection with this. In other words, we will be able to reconstruct the physicochemical conditions of its formation.

The composition of the soil in the area where the "Venera-14" module landed proved to be different. It corresponds to the composition of the oceanic tholeiitic basalts that are widely found on Earth. However, we cannot regard these rocks as the result of lava flows, as was done in the case of "Venera-13." It is more likely that they are the products of the accumulation of a mixture of ash and small crystalline fragments of rock and minerals that were ejected during explosive volcanic eruptions and then packed down. The absence of noticeable secondary changes in the rock is indicative of its youth, whereas the very fact of the explosive volcanic ejecta indicates the presence of considerable amounts of water in the magma. This brings in doubt the hypothesis of the primary impoverishment of Venus as far as water is concerned. The results of the experiments are exceptionally important for planetology as a whole and for the study of Venus in particular.

The "Venera-13" and "Venera-14" stations carry Soviet and French gamma-ray receivers that register suddenly appearing flares or, as they are called, gamma-ray bursts. By determining the difference between the times of arrival of gamma-bursts it is possible to compute the direction from which they arrived. The exact cause of their appearance is unknown. They usually last several seconds and probably appear in connection with large cosmic catastrophes. During the flights of the "Venera-13" and "Venera-14," about 30 bursts were registered. It is not possible to record them with terrestrial receivers, because they do not pass through the atmosphere. The study of gamma-bursts should clear up the nature of yet another type of the grandiose processes occurring in space.

Last year Soviet scientists completed the development of a refined theory of motion of the inner planets (Mercury Earth, Venus and Mars). It now makes it possible to precompute the distances between the planets with accuracy of up to 1 km and their speeds with an accuracy of about 1 cm/s. These computations are tens of thousands of times more accurate than those produced 20 years ago, before the appearance of radar astronomy and spacecraft flights to other planets. The theory is based on the general theory of relativity, which allows for the change in temporal and spatial relationships in gravitational fields, and utilizes both the most recent optical and radar measurements of the locations of the planets. The latter are now strikingly accurate: with our space radar located in the Crimea, we are measuring the distance to Venus with an error on the order of only 300 m.

The large, fully revolving radiotelescope, which is as tall as a 25-story building and has a mirror 70 m in diameter, will undoubtedly be a very important factor in space research now that it is in operation. At the present time it is the best radiotelescope of its class in the world, and it can be used both to transmit radio waves, concentrating them in a very narrow beam, and to receive them. It is used for communication with spacecraft (in particular, for the transmission of commands to the "Venera-13" and "Venera-14" stations and the reception of information from them), for locating the planets with radar and for radioastronomical observations.

In addition to scientific research in space, we have continued to develop and improve the space systems for regular observation of the Earth, in the interests of weather prediction, agriculture and forestry, sailors, geologists and navigation, communication and television broadcasting systems, all of which affect the national economy.

Thanks to satellite communications, in October 1980 a five-zone television broadcast of Central Television's First Program and a three-zone broadcast of its second program were introduced in the USSR. Right now central television broadcasts are transmitted from Moscow at a time convenient for viewers in a given zone. In all, more than 87 percent of the Soviet Union's population can receive a good-quality television broadcast.

The use of artificial Earth satellites with more powerful radio transmitters made it possible to simplify and make cheaper the receiving units for small populated points and ships in the maritime fleet operating in the northeastern sector of the Arctic. The "Ekran" satellite television broadcasting network, which utilizes these satellites, is truly massive. Right now it contains more than 2,000 receiving units.

The possibility of full coverage of the entire country with television broadcasting appeared with the creation of the satellite television system on the GHz band that is provisionally called "Moscow." It will make it possible to service any regions in the country, with particular emphasis on the European part of the USSR, the Urals, Central Asia and the Far East, since there is no danger of the appearance of interference by ground services. The use of a more powerful transmitter and an antenna with a narrow radiation pattern in the "Gorizont" geostationary satellite made it possible to substantially simplify and reduce the cost of a receiving station in comparison with the "Orbita station and to change from antennas with a mirror diameter of 12 m to simple and inexpensive antennas 2.5 m in diameter. Right now we are successfully operating a network of 100 such stations and have tested the possibility of using them to receive images of newspaper pages. With the help of this system, newspapers can be sent directly to typography, which eliminates the need for constructing expensive ground connection lines and will make it possible to increase substantially the number of cities in which central newspapers are published simultaneously with their appearance in Moscow.

On the basis of the "Gorizont" satellites, we are successfully developing the "Intersputnik" international satellite communication organization. At the present time its members are Afghanistan, Bulgaria, Hungary, Vietnam, the GDR, Cuba, Mongolia, Poland, Romania, Czechoslovakia, the USSR, Yemen, Laos and Syria.

About 40 percent of all the television exchanges among these countries are realized through the network of "Intersputnik" ground stations, and since 1 February 1982 we have organized a daily television exchange of news.

The length of this article does not permit me to enumerate all the events that have taken place recently, but the successes achieved and their value are obvious from what I have been able to mention. With full confidence I can say that we will greet the 60th anniversary of the formation of the USSR with new and great achievements in investigating and using space for peaceful purposes and in the interest of the national economy.

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11746
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DEVELOPMENT OF AND BENEFITS FROM SATELLITE SYSTEMS

Moscow SOTSIALISTICHESKAYA INDUSTRIYA in Russian 3 Oct 82 p 4

[Article by V. Zubkov (the newspaper's special correspondent): "Orbiting Patrol: Reportage from the Enterprise where the 'Meteor-Priroda' Satellites Are Built"]

> [Text] A quarter of a century ago, on 4 October 1957, the first satellite in the history of mankind was launched in the Soviet Union, which marked the beginning of the space age.

The spot pulsing on the screen left no doubt: There was a fire in the taiga. But the operator did not rush to scramble the helicopters with landing parties or call the ground fire units. He merely sent the coordinates for the fire center to his colleagues. And they immediately sat down at the monitor which "looks over" the images of the earth sent from a satellite. And the computer next to it helped the specialists analyze the direction of winds and status of the cloud cover "at the approaches" to the fire.

Finally, an approaching front of clouds is found: The wind is driving them to the center of the fire. Now, it is aviation's turn. At the computed time, the aircraft with a load of chemicals fly out to the clouds soaked with moisture. When the clouds are hanging above the taiga "bonfire," the pilots seed them with reagents. And down pours a heavy rain which forces the fire to yield.

This is the operational concept planned by scientists and specialists for the Meteor-Priroda space system based on second-generation Meteor satellites.

One of these satellites, a most complex four-meter structure, stands here in the center of a resonant hall in a bowl with tile facing that is called a basin at the enterprise. Rings for the body with a 1.5-meter diameter lie nearby; they are not needed now. Finishing work is underway on the numerous satellite systems. The operations are mandatory and not very simple: Although the design consists largely of series devices, it has to be improved from machine to machine.

"Not too long ago, we had consoles with about 30 operators sitting at them very close along the edge of the "basin," says one of the group directors, Yu. Trifonov, candidate of engineering science. "Noise, confusion and of course, the inevitable mistakes. Now, a small brigade does the checkout. And they sit over there in the hall. And the "status" of the satellite is checked by a computer using a special program by using sensors. It handles in two to three hours the same work that used to require days and weeks...."

We came down into this hall when the windows were already covered with the evening blue. Finishing the work day, the operators summed up the results.

"Everything is on schedule!" one of them said. "No more thinking for today. Let's run this piece of the program once more tomorrow...."

To tell the truth, such a measured pace somehow even disappointed me: They are making space hardware, but they go home exactly on schedule.

"For them, this technology is now everyday, routine work," says Yuriy Valer'yevich, who sensed my feeling. "This is not the first satellite...."

The first satellite was not made here and not this way. Those who prepared for its launch did not have all this apparatus and equipment. They would have hardly found a use for it.

It was in 1954 when the little known official document was written by S. P. Korolev, who put the question to the government of beginning work on a satellite based on the intercontinental missiles that had been built then. The possibility of launching such satellites had been discussed in theoretical research performed by a group led by Professor M. K. Tikhonravov since 1948. Based on this, S. P. Korolev wrote:

"...Development of the new hardware now underway allows talking about the possibility of developing a satellite in the next few years.... By some reduction in payload weight, one could attain the end velocity of 8000 m/s needed for a satellite. It seems to me that now is an opportune and expedient time to organize a scientific research department to perform the first exploratory work on a satellite and the more detailed elaboration of the complex of questions related to this problem...."

At the beginning of 1956, a special commission on satellites was set up; it was headed by M. V. Keldysh and included S. P. Korolev and M. K. Tikhonravov. For all those participating in this effort, it set the task: Develop and manufacture the first satellite literally within a very few months. Aleksey Ivanov, one of those taking part in this effort, later recalled:

"...There emerged in the shop a special room, freshly painted, with white silk blinds at the windows and plush wine-colored drapes at the doors. Such a place had never been seen before in a plant. Having seen it, we understood: No simple order had come into the plant; it was a very special one. The process engineers demanded special cleanliness (surfaces were polished). Fitters and assemblers donned white smocks and white cotton gloves. Satellite parts were put on stands covered with black velvet...."

The first satellite was planned as an entire laboratory, where the weight of the scientific apparatus had to be almost a ton. But in engineering, everything does not always come out as planned and on schedule. And things were no different in this case too. The schedules had to be readjusted: The launch vehicle was almost ready. It became clear that the capability of launching the satellite into orbit would emerge before it had been made. Therefore, the decision was made to build a simpler design.

So then there emerged on the drawings a spherical apparatus with a diameter of a little less than 60 centimeters. Its "filling" was also simple: three silver-zinc batteries to power the radio transmitter-direction finder, the transmitter itself with a remote switch for different frequency bands, and a fan. On the outside were four rod antennas. And everything was within the limits of 83.6 kilograms.

This little ball, launched into orbit on 4 October 1957, opened the space age in the history of man. Later, a satellite with Layka on board was launched. And then, the apparatus that had been planned as the first was launched too. This way was even more logical: from the simple to the complex.

Recalling the events of those years, the person I was talking to assesses them by his own measures:

"The launch of the first satellite led to rapid development of aerospace engineering and technology, electronics, radio and television, chemistry, biology and medicine. It can be said confidently that from that time on, all science and the leading sectors of industry went on a fundamentally new scale of reporting their achievements: from the position of strict space standards...."

"Nevertheless, Yuriy Valer'yevich, what is space doing for us?"

"I think that even a superficial answer to that question would fill an entire volume. Take our weather system for example. In it there are three Meteor-2 second generation satellites, the orbits of which are inclined 120° relative to each other. Because of this, within the 15 orbits that each satellite makes around the earth every twenty-four hours, it passes over our country's territory six to seven times. And the complex of apparatus installed on board which senses the earth in different bands of the spectrum gathers a lot of information."

"But what does it do with it?"

"Some of this information is continuously transmitted to earth, and it can be used not only by us in this country, but anywhere there is a receiver. And some is "dumped" over the main receiving sites in Moscow, Novosibirsk and Khabarovsk. From there, it is sent to the users which include enterprises and organizations in 20 ministries and departments. Also, the weather charts compiled from the satellite data are sent twice a day abroad...."

In his office, Yu. V. Trifonov placed color photographs of our country's territory on the desk.

"An advantage of the satellite system is that it operates essentially without interruption," he says. "Also, the orbiting stations and manned ships for a number of reasons don't "get" higher than the 50th parallel. But the satellite system covers the entire territory of the country. Thus, studying the earth with it substantially complements the observations from on board the manned craft. And vice versa...."

The validity of this statement becomes evident when you recall that during the flight on board the Salyut-6, V. Kovalenok and A. Ivanchenkov, studying the ocean, detected colored spots on its surface: They turned out to be accumulations of plankton. These observations were of interest to the satellite developers. It was soon discovered that these spots could be detected only with a side view. And the apparatus arranged in the appropriate way was not long in showing up on board the satellites.

"In winter, from the photographs of mountains and fields transmitted from orbit, hydrologists can judge the supply of snow and expected level of high water and even plan measures to retain the snow," the scientist says. "The advantages of space information were also quickly appreciated by the seamen: It helps them plot optimal routes and discover passages among the ice. According to data from the USSR Ministry of the Maritime Fleet, this information saves up to 40 million rubles a year. But the geologists have become, perhaps, the most active supporters of sensing from space. I'll give you just one example: In Tyumen, the satellites helped them refine the boundaries of oil deposits by 1,000 kilometers. Imagine how much money and time this saved!"

Now a new active consumer of satellite information has emerged: agriculture. For it, the photographs processed on a computer are becoming a real storehouse of information. From them, one can determine what crops have been planted in a particular sector and assess germination and soil moisture content. Naturally, even with the most sensitive instrument, the voracious ground beetle cannot be seen from space altitudes. But the areas infested with this pest can in time be detected by using satellites.

"If you talk about the prospects of the Meteor-Priroda complex," Yu. Trifonov says in finishing our conversation, "it has to become a permanently operating global system. This satellite patrol has to be equipped with the apparatus capable of making the most minute measurements. Why? For example, in the view of Academician Marchuk, there is a definite relation between the temperature in the areas where the Gulf Stream originates and the weather in Europe. But the variations in this temperature are not large. That's why systems are needed that are capable of measuring it with an accuracy of tenths of a degree...."

Satellite developers are also thinking of equipping the space patrol with instruments for precision analysis of the magnetic situation; judging from appearances, it too affects the weather. Also in their plans for the future are satellites that sense the earth by radar methods; neither clouds, nor fog will interfere with them. Day and night in any kind of weather, they will be vigilantly "scanning" the planet, helping us keep it rich and generous. But first, all satellite systems will undergo the strictest checkout in the "basin" of this enterprise.

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LAUNCH TABLE

LIST OF RECENT SOVIET SPACE LAUNCHES

Moscow TASS in English or Russian various dates

[Summary]

Date	Designation	Orbital Parameters			
		Apogee	Perigee	Period	Inclination
12 Jan 83	Cosmos-1428	1,017 km	972 km	104.7 min	82.9°
19 Jan 83	Cosmos-1429-- Cosmos-1436	1,513 km (Eight satellites launched by single booster)	1,449 km	115.3 min	74°
20 Jan 83	Cosmos-1437	678 km	629 km	97.6 min	81.2°
27 Jan 83	Cosmos-1438	254 km	213 km	88.9 min	70.4°
6 Feb 83	Cosmos-1439	371 km	180 km	89.7 min	70.4°
10 Feb 83	Cosmos-1440	293 km	223 km	89.3 min	82.3°
16 Feb 83	Cosmos-1441	667 km	632 km	97.5 min	81°
25 Feb 83	Cosmos-1442	364 km	180 km	89.6 min	67.2°

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May 13th 1983